TO THE 30th ANNIVERSARY OF THE SPECIAL ASTROPHYSICAL OBSERVATORY

In the fall 1996 a Conference dedicated to the 30th anniversary of the Special Astrophysical Observatory was held.

Below we present some reports delivered at this Conference.

Bull. Spec. Astrophys. Obs., 1998, 45, 17–38

Contribution of Institutes of the Academy of Sciences into creation of the 6 m telescope

N.N. Mikhelson

The Main Astronomical Observatory, Pulkovo, St.Petersburg, Russia

Received January 9 1997; accepted April 12, 1998.

Dedicated to the memory of the corresponding member of the USSR Academy of Sciences D.D. Maksutov who initiated construction of the 6 m telescope.

Corr. member of RAS D.D. Maksutov

1. Introduction

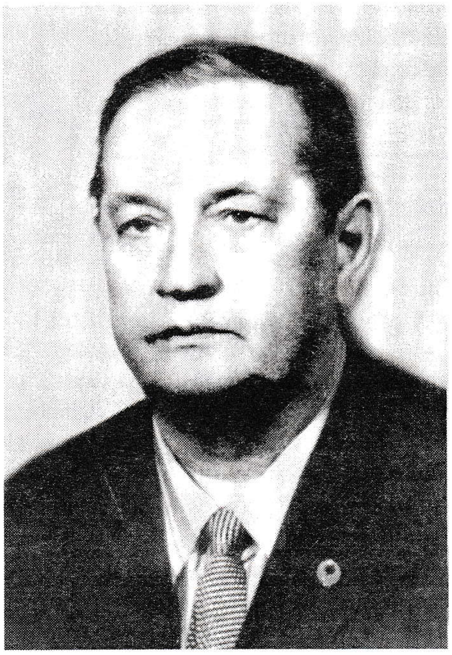
In the 19th century Russia held centre-stage in astronomy the world over. It was not without a reason that Simon Newcomb (1903), referring to B. Gould, called the Pulkovo Observatory "The Astronomy Capital of the World". It was made famous by the works of V.Ya. Strewe who equipped the observatory with the most elaborate astronomical instruments, allowing creation of the most accurate (contemporary) astronomical catalogues. The 15-inch (1839) and 30-inch (1885) refractors were the world's largest telescopes at that time. They enabled O.V. Strewe and G.O. Strewe to accomplish a fundamental study of many visual binary stars, and academicians F.A. Bredikhin and A.A. Belopolsky to develop astrophysical research at Pulkovo.

In the early 20th century, however, the USA began constructing large reflectors. In 1908, 1917 and 1948 reflectors with diameters of 1.5 m, 2.5 m and 5 m, respectively, were put into operation. To keep pace with this, the Russian Government, shortly before World War One, hired the British firm Grebb-Parsons to manufacture two telescopes: 0.82 m and 1 m reflectors. During World War Two both telescopes, as well as the two refractors at the Pulkovo Observatory and a number of smaller instruments at the Pulkovo, Crimean, Kharkov and other observatories, were destroyed.

To remedy the situation the State Optical and Mechanical Plant (SOMP) constructed meniscus telescopes of up to 0.5 m (for the Pulkovo and Crimean Observatories), and 0.52 m and 1 m Schmidt cameras

Acad. V.P. Linnik

Director of the Pulkovo Observatory Corr. mem. of RAS A.A. Mikhajlov



Prof. O.A. Melnikov

(both for the Byurakan Astrophysical Observatory), and 0.7 m reflectors (for other observatories) designed by P.V. Dobychin. The State Institute of Optics constructed a meniscus telescope AC-32 (for the Abastumani Observatory) designed by B.K. Ioannisiani.

Under the supervision of B.K. Ioannisiani a reflector (Shaine Mirror Telescope) with a mirror diameter of 2.6 m was designed at SOMP for the Crimean Observatory. However, all this could not bring us to the forefront in astrophysics. That is why in the autumn of 1951 D.D. Maksutov proposed to the Government of the USSR the idea of constructing a large telescope.

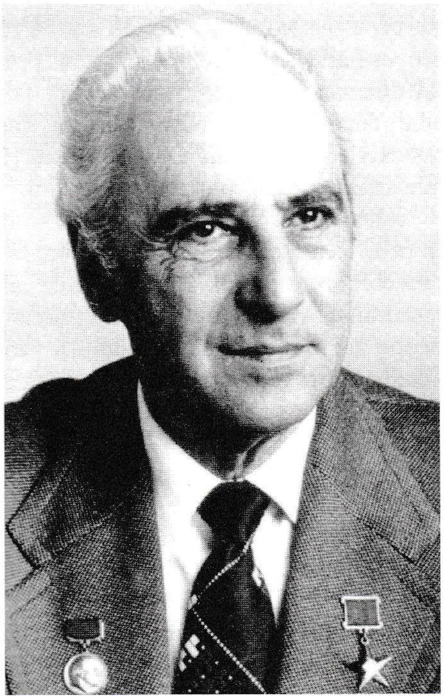
On September 21, 1951 the Presidium of the USSR AS passed a decision (No.377) in which the inadmissable lag between the state of instrumentation in the home observatories and the requirements of science was pointed out.

In the spring of 1952 the Government permitted the Academy of Sciences to start the relevant search activity for a place to build a large telescope.

2. The Joint Council of the Large Telescope

On May 10, 1952 the first meeting of a group of astronomers and engineers, presided over by acad. V.P. Linnik, was held in Pulkovo. The meeting was attended by the Director of the Pulkovo Observatory corr. mem. A.A. Mikhailov, acad. G.A. Shain, corr. mem. D.D. Maksutov, acad. M.P. Kostenko, chief designer of the Shine Mirror Telescope B.K. Ioannisiani, and well known astronomers corr.mem. M.S. Zverev, V.B. Nikonov, P.P. Dobronravin, prof. O.A. Mel'nikov and Eh.R. Mustel. V.P. Linnik asked the opinion of the meeting's participants about the possibilities for using an alt-azimuth mounting. A.A. Mikhailov noted that in such a mounting one would have to compensate for the field rotation. O.A. Mel'nikov formulated the tasks the telescope was intended for and spoke out on the benefits of an alt-azimuth mounting. G.A. Shain suggested opting for the 6 m telescope.

On May 12, 1952 a second meeting took place with the participation of the well-known telescope



Chief designer of the BTA B.K. Ioannisiani

designer P.V. Dobychin. At the meeting B.K. Ioannisiani asked if it was really necessary to emphasize that the mounting must be azimuth, and that it was surely a matter of the designers to decide. However, V.P. Linnik insisted that the type of mounting should be specified since to settle the matter the specialists from the Institute of Automation would be invited. The point is that control of an alt-azimuth telescope is radically different from the conventional and comparatively simple control of an equatorial telescope. To choose a material for the telescope main mirror (glass or metal was usually employed) it was decided to bring in A.A. Bajkov Institute of Metallurgy the Scientific Research Institute–13, and the Institute of Chemical Silicates. For the calculations of deformation of the main mirror the Institute of Machine Engineering, the Institute of Mechanics and the Leningrad Polytechnical Institute were involved. The necessity of including the Leningrad Optical-Mechanical Firm (LOMO was then still known as the State Optical and Mechanical Plant) and the Lytkarino Plant of optical glass was also never in doubt.

In his speech D.D. Maksutov evaluated the characteristics, merits and disadvantages of glass (pyrex) and metal mirrors. With the latters Maksuṭov (1937, 1984) was dealing as early as thirties. He explained the necessity of using a field corrector and the possibility of employing in the capacity of such an aspherical meniscus. "We should seek — he said — not after the dimensions of the telescope, but after the quality and selection of its site of installation; the optical arrangement could be either classical, with a correcting meniscus, spherical main mirror, with compensation for aberrations through the secondary mirror and a lens or meniscus corrector, or a purely mirror aplanatic system".

In the autumn of 1952 the Department of Astronomical Instrument-making headed by D.D. Maksutov was created at the Pulkovo Observatory. B.K. Ioannisiani took part in the work of the Department. The Department was composed of four groups: the Optics Computation Group (headed by D.D. Maksutov, with colleagues N.V. Merman, M.A. Sosnina, T.S. Belorossova, G.V. Borodina, and laboratory assistant I.D. Yumshanova), the Design Office (headed by B.K. Ioannisiani, with V.G. Il'in, Yu.S. Streletzki, A.V. Schumacher, N.A. Shkutova, T.S. Gerasimova, I.F. Saksina, E.G. Grossvald, and others), the Group for Developing the Control System (N.N. Mikhelson, Yu.A. Belyaev, V.S. Sumin, Z.V. Dravskikh, L.V. Nikolayeva, K.A. Naidenova, A.V. Korolev, and Yu.A. Kozlov). The group for investigation of astronomical climate and selection a suitable site for the telescope was organized somewhat later on, in 1955. N.I. Kucherov became the chief of this group with colleagues G.I. Bolshakova, N.V. Bystrova, O.B. Vasil'ev, G.Ya. Vasil'eva, A.Kh. and Sh.P. Darchiya, A.N. Demidova, A.F. Sukhonos, and many other scientists from different observatories of the country, as well as students and amateur astronomers.

A number of Institutes of the Academy of Sciences and other departments were engaged in the work on the large telescope: the Institute of Automation and Electromechanics (M.P. Kostenko, Yu.A. Sabinin, P.V. Nikolaev, I.P. Rozhnova and others), the Institute of Mechanics (prof. A.L. Goldenvejzer), the A.A. Bardin Institute of Metals, the Leningrad Polytechnical Institute (corr. mem. A.I. Lourie and prof. L.G. Lojtsyansky), the Institute of Machine Engineering, and the State Scientific Research Institute of Quartz Glass (V.P. Pryanishnikov). Later inclusions were the Leningrad Department of the Scientific Research Institute of Design (director I.A. Ostanin and chief architect D.Kh. Enikeev), the Soyuzprommekhanizatsiya Trust (chief engineer N.D. Tatarinov and chief designer A.P. Eliseev), the Yuzhstalconstruktsiya Trust (M.Ya. Vishnevskij), the Institute 993 (N.M. Yakimenko), the Lenin Works, the Leningrad Optical Mechanical Firm, the State Optical Institute, and others.

A Joint Council was created at the Pulkovo Observatory to guide the implementation of all work. Acad. V.P. Linnik was originally at the head of this council, but in 1961 the Director of the Pulkovo Observatory acad. A.A. Mikhailov took over. The council regularly discussed the progress of work in all the institutes linked to the project. In all, more than thirty sittings of the council took place between 1952 and 1967. Interest in the work was also expressed by the President of the Academy of Sciences, acad. M.V. Keldysh, the Secretary of the General Physics and Astronomy Department of AS, acad. L.A. Artsimovich, and the Astronomical Council (AS) through its Chairman, corr. mem. Eh.R. Mustel.

The project to build a 6 m telescope in the USSR was first publicly revealed by the Chairman of the Council of Ministers, N.A. Kosygin, in the summer of 1958 in Moscow, during the tenth Congress of the International Astronomical Union (Vestnik USSR AS, 1958).

3. Work of the Astronomical Instrument-making Department at the Pulkovo Observatory

An electric atmosphere reigned in the Astronomical Instrument-making Department the spirit of which came from Dmitrij Dmitrievich Maksutov. For the creation of the large telescope it was necessary to solve a great number of problems, and carry out a large amount of modelling and research. For decisions on numerous technical questions it was deemed essential to construct an experimental telescope (700 mm in diameter) at Pulkovo. Before its erection three fundamental tasks were formulated:

1. To check the functioning of a lens coma corrector for a paraboloid reflector.
2. To investigate the properties of a metal mirror.
3. To test the opportunity of using new principles for controlling the telescope.

This telescope received the name RM-700 (model reflector, 700 mm in diameter). The subsequent work of the Astronomical Instrument-making Department and Optical-Mechanical Workshop was to a considerable extent concentrated on the creation of this telescope.

4. The work of the Optical Group within the Astronomical Instrument-making Department; calculation of the optics of the large telescope and related work

The optical group under the leadership of D.D. Maksutov started by accumulating experience of astronomical telescope calculations. N.V. Merman (1958) calculated the optics of the 700 mm meniscus lunar-planetary telescope, which was subsequently built in the workshops of the Pulkovo observatory. To facilitate the expedition which would choose the future installation site of the large telescope, N.V. Merman and T.S. Belorossova calculated two light meniscus Cassegrain type telescopes TEM-140 and ATM-140. The telescopes had the diameters 140 mm, the equivalent focal distance 2930 mm, and a very thorough aberrational correction. Construction of the telescopes was carried out in the Design Office (DO) of the Instrument-making Department by Yu.S. Streletskij, A.V. Schumacher and I.F. Saksina under the leadership of B.K. Ioannisiani. The telescopes TEM-140 were erected on a parallactic mounting, and had a clock mechanism driven by a gramophone string. The telescope ATM-140 had an azimuth mounting and a specially improved optical system with slightly elliptical main mirror. This optical system ensured a field upto $1°25''$.

For the 6 m telescope it was, first of all, necessary to select a relative aperture. A long-focus mirror with a low focal ratio is considerably easier to make than a high focal ratio one, because in the latter the paraboloid deviation from the sphere is much larger. A long-focus main mirror would necessitate the manufacture of a long telescope tube and a dome of large diameter. A long tube, though, may sag quite considerably; this will bring about a disadjustment of the optical system and the appearance of supplementary coma, constant throughout the whole field. Moreover, the cost of the telescope and dome would increase with any extension in the length of the tube and diameter of the dome. In selecting the telescope's diameter D.D. Maksutov was very careful. Twice (October 9, 1957 and December 12, 1957) he suggested settling for the 4 m diameter, but V.P. Linnik, V.A. Ambartsumian and others insisted on the 6 m diameter. Originally, calculations of optics were made for the relative aperture of the main mirror 1:3. After evaluating difficulties of manufacture D.D. Maksutov concentrated his choice on the aperture 1:4. With a main mirror diameter of 6 m the focal distance is 24 m, with a somewhat longer tube. On April 3, 1960 a meeting of the Joint Council discussed the preliminary specification for the telescope's optics. The specification was drawn up by D.D.Maksutov. It included the primary focus with uviol meniscus corrector of Cassegrain type, Nasmyth and coude. Subsequently the Cassegrain and coude foci were rejected, leaving only the prime focus and two Nasmyth foci.

Utilization of the hyperbolic main reflector would allow the aplanatic Ritchey-Chretien arrangement to be employed, which is free of coma and therefore has a comparatively large field. However, in the Ritchey-Chretien system the aspherisities of the main and secondary mirror's essentially increase, and the methods of control become complicated. Domestic industry at that time did not have the experience in manufacturing high quality astronomical mirrors with complex aspherical surfaces. Therefore D.D. Maksutov did not risk recommending the Ritchey-Chretien system with hyperbolic main mirror, opting instead for the classical Cassegrain system, with its easier to manufacture parabolic main mirror.

A field with satisfactory image quality (1 arcsec) in the focus of the parabolic mirror with a relative aperture 1:4 does not exceed 1.5 arcmin. To increase it a corrector is needed. Through the energy of D.D. Maksutov's group 62 variants of the corrector with a diameter of 1 m were calculated, including ones with slight aspherical meniscus, double aspherical meniscus correcting for chromatism of magnification, and a corrector of Ross type. However, in 1960 B.K. Ioannisiani requested the corrector's diameter to be reduced to 700 mm. Computations for the corrector were carried out by D.D. Maksutov, N.V. Merman, T.S. Belorossova and M.A. Sosnina with the participation of I.D. Yumshanova and S.V. Borodina.

In those years there were no electronic computers. Calculations were made by utilizing tables of logarithms (Vega) and mechanic calculating machines. Later the semi-automatic calculating machines Rainmetal and Mercedes emerged. T.S. Belorossova and N.V. Merman developed formulae to calculate a slanting beam across the second-order surface (Belorossova and Merman, 1968). The formulae were specially deduced for the available calculating techniques.

The final variant of the Ross type afocal corrector, computed at Pulkovo (Belorossova et al., 1975), contained three lenses of K8 glass (including the Piazzi-Smith field corrector lens (Table 1)). The corrector ensured a theoretical resolution on the optical axis $0\farcs07$ and at the edge of the field with the diameter $2W = 10''$ it was $0\farcs61$. 100 % of the light (disregarding diffraction) concentrates in the centre of the field in a circle 8.4 μ m in diameter, while at the edge of the field the circle is 73 μ m, 80 % of the light concentrates in circles 8.4 and 58μ m, and 50 % in circles 8.4 and 47 μ m, respectively. This calculation was communicated to LOMO and taken up for implementation. Later at LOMO M.V. Lobachev and L.E. Yakukhnova (1977) calculated three-lens systems for the Nasmyth system: shortening (1:14.6), lengthening (1:58.2), and inverting, the last comprising of two three-lens components. The components ensured a parallel beam. This could allow installation of interference-polarization filters.

Constructional elements of the corrector are cited in Table 1. The possibility of using optical fused-glass quartz for all three corrector lenses of the prime focus of the telescope was studied. With this in mind, contact was established with the quartz-glass laboratory at the M.I. Lomonosov Plant (now the State Scientific Research Institute of Quartz Glass), headed by V.P. Pryanishnikov. An excellent specimen of fused quartz was produced in this laboratory with a diameter of about 220 mm. Also were investigated two-mirror configurations with squares of eccentricities of the main mirror 0.0 (spherical mirror), 1.0 (paraboloid), and 1.2785 (hyperboloid) with a corrector in the shape of a thin aspherical meniscus, of a thick aspherical meniscus, and of a two-lens afocal system.

Таблица 1: *Computed constructional elements of the BTA prime focus corrector*

R	D	Material
-48000*	-21456	air
+6425	-50	K8
-2364.9	-2	air
-1266.6	-70	K8
-1846	-2405.5	air
+721.86	-16**	K8
-1017.0		

* Main mirror $e^2 = 1.0$

** Piazzi-Smith lens

Compensating methods suggested for the first time by D.D. Maksutov (1932) allow the use of considerably smaller dimensions and accordingly a comparatively cheaper concave spherical mirror for controlling the big mirror. Such a method was employed for investigation of the main mirror (diameter 2.6 m) of the Shain mirror telescope, and gave a big saving of both resources and time. D.D. Maksutov (1957) and M.A. Sosnina (1958, 1968) improved the compensating method after considering the opportunity of investigating secondary convex hyperbolic mirrors and tolerances for the system of compensation investigation, and also the method of investigating the correcting meniscus (diameter 0.5 m) for the Shain mirror telescope. M.A. Sosnina (1968) examined the use of the compensation method for investigation of aspherical mirrors with $e^2 = 0.5, 1.0, 1.5$ and 2.0 with relative apertures 1:3, 1:4 and 1:5. In this work Pan Tziun Hua, a post-graduate student of D.D. Maksutov, participated, who at the present time is a well-known astronomical optics expert in China. He suggested (Pan Tziun Hua, 1961) using a concave elliptical mirror in the compensation method to investigate the convex secondary mirror of the telescope. He (Pan Tziun Hua, 1960) also carried out an investigation of two-mirror systems equipped with main mirrors of different shape (from $e_1^2 = -2$ to $e_1^2 = +2$) and differing relative apertures. For the investigation of the main mirror M.A. Sosnina (1968) calculated an Offner lense compensator with a diameter of 300 mm; this was considerably cheaper than the concave spherical mirror of 2.6 m in diameter which was regarded as an alternative.

D.D. Maksutov perfectly correctly thought that the efficiency of a big telescope which possesses a small field will be essentially higher if next to it, at the same observatory, a wide-field telescope with a field up to $2W = 2\overset{\circ}{.}6$ is mounted. The computation of such a telescope, with a hyperbolic mirror of a 2.6 m and a 3-lens corrector, was carried out by T.S. Belorossova, M.A. Sosnina and N.V. Merman (1964) under the guidance of D.D. Maksutov. Unfortunately the telescope was never built.

In connection with this work T.S. Belorossova, D.D. Maksutov, N.V. Merman, and M.A. Sosnina (1961) carried out a comparison of properties of meniscus systems, Richter-Slefogda and Schmidt systems at different relative apertures from 1:2 to 1:4, but a little while later they (Merman and Sosnina, 1965) developed an original system — a sort of hybrid of the Schmidt system with the meniscus Maksutov system.

5. Choice of construction of the main and secondary mirrors of the Big Telescope and investigation of their weight deformations

The construction choice of the main mirror was one of the crucial moments. An excessively thin mirror will sag under its own weight, and its deformations will be dependent on telescope inclination. There were grounds to fear that a ribbed mirror (like the 5 m Palomar telescope) would be too "nervous" — the gradient of temperatures in the ribs and on the surface between them would lead to distortions. Unfortunately there was no success in involving the Moscow Institute of Oil, which possessed a unique grid differential analyser suitable for carrying out calculations of complex temperature fields. Questions about the form of the rear surface, the thickness of the mirror, the necessary number of supports and their distribution all remained open. Calculations via the elasticity theory methods were fulfilled at the Leningrad Polytechnic Institute (corr. mem A.I. Lourie (chief), colleagues V.S. Chernina (1964), T.V. Budnikova (Budnikova and Friedman, 1964), V.A. Pal'mov, V.A. Pupyrev (1964), V.M. Friedman (1964), and in Moscow at the Institute of Mechanics of the USSR AS (prof. A.L. Gol'denveizer). However, in view of the complex configuration of the mirror it became necessary to introduce simplifying assumptions.

At Pulkovo E.G. Grossvald and K.S. Tavastsherna (with the participation of G.A. Batranina, and consultations with T.D. Maksutova (Leningrad State University) investigated the mirror shape using the optical-polarization modelling method. They used epoxide resin for the main mirror (Grossvald, 1965) and igdantin for the secondary mirror (Grossvald and Tavastsherna, 1966). Epoxide resin has two states. One of these has a big modulus of elasticity (Young modulus), but easily softens when warmed, the other is the opposite way round. This allows one to record deformation. Engineer E.G. Grossvald developed a special centrifuge: a long beam attached in the middle on a verticle spindle. On the ends of the beam there were attached cylindrical thermostats in which the epoxide resin model mirrors were placed. The centrifuge was situated in the basement of the old mechanical workshop building at the Pulkovo Observatory. The control of the centrifuge and thermostats was carried out from an adjacent room. Centrifugal force exaggerated the force on the model, which warmed up in the centrifuge until the temperature softened the first resin component. The result was that the model deformed under the action of centrifugal force. It then was cooled down (without removal of the load) and the deformations were "frozen". The frozen deformations were gauged on a microscope. Recomputation of the model on the real mirror was made using the theory of similarity. By such a method E.G.Grossvald, K.S. Tavastsherna and G.A. Batranina studied 11 different construction variants of the main mirror; the change in relative thickness of the mirror, the number of support units, the form of the rear surface, and the form of the ribs. Three experiments were carried out for each model. One of these models is displayed in the Pulkovo Observatory museum. The experimental data showed that for the finally accepted construction variant of the mirror the deviation of its front surface from the closest sphere, caused by the weight deformations, does not exceed 0.03 μm. The theoretical calculations performed by the groups of A.I. Lurie and A.L. Goldenveizer and also the subsequent calculations of N.S. Samofal at LOMO gave similar results.

Analysing the well-known large mirrors and their support systems Danzhon and Kouder (1935) determined a connection between the diameter of the mirror, its relative thickness, and deformations for different support systems. E.G. Grossvald (1967) compared experimentally the results with the data of Danzhon and Kouder. The relation she obtained was represented by curvilinear surfaces of the fourth order in the form of spatial graphics.

The results of calculations and experimental investigations into the deformations of the main mirror were repeatedly discussed at the Joint Council meetings. Due to these results, on November 5, 1961, at a conference with the President of the USSR AS, M.V. Keldysh, it was acknowledged necessary to shape the main mirror to a form of meniscus with a relative thickness close to 1/10. It would have sixty cavities for the support units distributed over four zones of the mirror, and a small technological central hole.

N.N. Mikhelson (1965) examined the Lassel principle of support for application to mirrors with flat and convex rear surfaces, and their errors. One of the two possible construction variants of support for a meniscus-like mirror, described by N.N. Mikhelson, was used in the BTA.

Study of deformations of the secondary mirror and the choice of its fastening system were carried out at Pulkovo by E.G. Grossvald's group and at LOMO under the guidance of N.S. Samofal. He conducted the calculation using the elasticity theory, while at Pulkovo the method of modelling on forge mass (igdantin) was adopted. The forge mass is a gel which resembles softened joiner's glue. Models with flat, concave and convex back surfaces with a central hole and without it, models of equal weight and equal thickness, models with six points of support on the rim and with support in the centre with different stresses were investigated. The models were mounted on the platform of a special measuring device constructed by engineer N.A.Shkutova. The model could turn while the measuring head had displacement along the radius. Measurements were made with a feeler with micrometer feed and with a needle-shaped electric contact. The calibration of forge mass samples was carried out with a tenzor-measuring device designed by engineer I.F. Saksina. The results of the numerous experiments carried out by E.G. Grossvald, K.S. Tavastsherna and G.A. Batranina, and also the computations of N.S. Samofal, showed that in addition to the periphery support system it was necessary to support the mirror in the centre with a strength of 0.4 of the mass weight of the mirror. In May 1964 the results of the experiments were communicated to LOMO.

6. The telescope tube design

Attention was also given to construction of the tube. It was not doubted that the supporting structure had to be of Serryurjera as was first employed in the 5 m Palomar telescope. But, would it have a light, solid exterior or interior sheath (the "closed" type tube), or remain truss (the "open" type tube)? This question necessitated an answer.

At this time the British firm Grebb and Parsons built a reflector with binary tube with a diameter of 1.93 m for the observatory in Haute Provence, France (Couder, 1953): externally of metal and internally a metal grid. Ventillators were mounted on the external tube and on the cell of the mirror. The air was sucked in through the top section of the tube, gradually escaped through the grid, and was thrown out by means of the ventilators in the dome. In the tube a laminar flux of air was created. The top section of the tube and the mechanisms of the secondary mirror had a favourable aerodynamic configuration. In a discussion with D.D. Maksutov Couder said that such a "blowing through" of the tube would improve the quality of the image, if the external atmosphere (outside the dome) was quiet. Developing this idea D.D. Maksutov suggested connecting of the telescope with a window in the wind-protector blind, by means of a soft funnel on the upper edge of the tube. This funnel form would remind one of a tulip. At that time the French film "Fanfan Tulip" was widely screened in our country and, always the joker, D.D. Maksutov called this bell-shaped funnel "fanfan". This name consequently stuck. For the 2.6 m reflector of the Shain mirror telescope, constructed for the Crimean Astrophysical Observatory, a possibility was envisaged of installation within the serryurjera construction a light metal collapsible tube with ventilators and a netted sleeve inside it, and their connection to the wind-protector blind through the help of fanfan. Unfortunately a live test on this telescope was not carried out.

T.N. Golovanova and K.L. Mench, designers from the Design Office at the Pulkovo Observatory, designed a binary reflector DT-200. Each of the two parallel tubes had a spherical mirror of 200 mm in diameter. The Cassegrain system with an equivalent focal distance of 8.04 m and a 14-fold magnification eyepiece ensured a magnification of 470 times and allowed the observation of diffraction image of stars. On the inside of each of the skeleton tubes it was possible to fit a light carton sheath, on the interior face of which metal foils were glued. In order to negate the small (unavoidable) difference in the quality of the mirrors, the sheath could be rearranged from one tube to another. There was no blowing-through. Nevertheless, the observations carried out by T.N. Golovanova and K.L. Mench (1956) in Pulkovo and the Crimea showed, with certainty, the advantage of the closed type tube (Golovanova and Mench, 1956).

Through the energy of the Pulkovo observatory and the Institute of Automation and Electromechanics the principle of employing a tracking system to compensate for the flexure of the telescope's tube, suggested by B.K. Ioannisiani, was successfully tested (Goreva et al., 1963).

7. The choice of material for the BTA's mirror, and treatment of the mirror for the PM-700

As early as the 1930s D.D. Maksutov had experimented with metal mirrors (Newcomb, 1903; Maksutov, 1937; 1948). Metal, when compared with glass, has high thermal conductivity leading to a quick levelling of the temperature gradients. This rules out thermal strains which distort the mirror surface. In connection with this the A.A. Baikov Institute of Metallurgy was commissioned to develop the formula, conditions of casting, and annealing of a special grade of rustless steel. From several grades developed in this institution one was chosen. It was the most corrosion resistant and the best for polishing. The Lenin plant in Leningrad casted a blank mirror with ribbed rear surface for the projected Pulkovo telescope RM-700. This blank had an outer diameter of 720 mm, a central thickness of 104 mm and a central aperture of 175 mm. The thickness of the rib was about 20 mm, the facial surface between the ribs about 30 mm. To remove the residual stress the factory performed a thorough annealing of the blank. Possible deformations of the facial surface of the ribbed mirror under the action of its own weight, when being supported at 9 points, were experimentally investigated by B.G. Grossvald (1961) on models of epoxide resin.

By that time the optical workshop at the Pulkovo Observatory had been fitted out with the optical machines КОС-750 and ШП-700, which were suitable for treatment of 700 mm diameter mirrors. In addition it acquired the unique interferometer ИТ-40, the multipurpose shadow bench УТС-20 (LOMO), and a series of shady devices developed and produced by the efforts and manufacture of both LOMO and itself (Yu.S. Streletski, I.F. Saksina).

After the rough and fine grinding of the mirror had been carried out at the Pulkovo Observatory optical workshop, its polishing was begun. An optically ideal sphere was very quickly obtained. The process of parabolizing was started. At this stage an optician cuts away the resin on the polisher so that the zones of the mirror to be made deeper would be heated up through friction stronger than the zones which did not need to be polished away. Due to thermal expansion the zones of the mirror heated through friction bulge and are ground away. When the mirror cools they will sink. To do this on glass is comparatively easy, but on metal, because of its high thermal conductivity, it is almost impossible to attain a temperature gradient and the corresponding relief projection. D.D. Maksutov suggested glueing a layer of rubber (thickness of about 7 mm) onto the hard polisher and on this apply the polishing resin. The grinding and polishing of the mirror were carried out by the experienced opticians Yu.F. Shkolnikov and K.A. Voronkov, under the direction of D.D. Maksutov and V.G. Shreiber. Engineer Yu.P. Platonov took part in this work at the last stage.

N.N. Mikhelson (1958) fixed his attention on beryllium as a possible material for the manufacture of astronomical mirrors. Its Young's modulus is 1.5 times higher than that of steel, but the density is only 1.85. Beryllium possesses a higher hardness. A small sample was successfully polished in the optical workshop at Pulkovo. The main shortcoming of beryllium was its considerable cost and toxicity. This, however, did not stop the Americans in 1969 from furnishing a GEP telescope with a beryllium main mirror of 940 mm (Mintz and Jackson, 1969). Zh.M. Loretsyan (1967a,b,c), at that time a post-graduate student of Maksutov, studied a great number of diverse aluminium-based alloys, and also samples from steel. The work was carried out at Pulkovo and the Institute of Metals. However, because of lack of experience in the founding, annealing and grinding of metal mirrors of large dimensions it was decided at a meeting of the Joint Council on the April 14, 1958, to concentrate on glass. In connection with this D.D. Maksutov said with regret, "we have to accept superpyrex, but metal mirrors must not be forgotten". At a meeting on July 5–6, 1960, attended by the leading specialists of the glass industry, this decision was finally sanctioned.

8. Mounting

A tube of a telescope carries optical elements — the mirrors and lens corrector. The tube itself is supported by the so-called telescope mounting. This mounting allows one to aim the telescope's tube at any point in the sky. For this to happen it is necessary to ensure the tube's rotation around two perpendicular axes. Up to the nineteenth century instruments used alt-azimuth mounting where one axis was vertical and the other horizontal. As early as the beginning of the XVII century the large instruments of Gershal had such a mounting. H. Scheiner, and later J. Short (mid-XVIII Century) and J. Ramsden (end-XVIII Century), not only suggested but also manufactured some instruments on equatorial (the so-called parallactic) mounting, in which one axis (polar) is directed to the celestial pole and the other (declination axis) lies in the celestial equator plane. The main advantage of an equatorial mounting is that after the telescope has been pointed at the object it suffices to be rotated at constant speed around the polar axis alone. Only in 1805, by equipping it with a clock mechanism, did J. Frauenhoffer bring the equatorial mounting to a state of perfection. Subsequently, all big telescopes, right up to the 5 m Palomar reflector, were erected on parallactic mountings.

The choice of mounting for the big telescope began in the Design Office (Astronomical Instrument-making Department) under the supervision of B.K. Ioannisiani. Originally the Palomar type mounting was examined but it quickly became clear that because of big weight deformations it would be impossible to employ it on the 6 m telescope. Following this, the Design Office, persuing a suggestion by Yu.S. Streletski, worked over the original equatorial mounting (Ioannisiani, 1970). It consisted of two hemispheres (Fig. 1), linked by a short, strong polar axis. The southern hemisphere is intended for the alignment of the polar axis, while the northern takes the weight of the instrument. On the diametric plane two short forks were mounted which supported the tube of the telescope. The northern hemisphere was provided with a notch so that the instrument could be pointed at the southern part of the sky close to the horizon. The centre of gravity of the telescope's tube and all its moving parts was situated on the intersection of the polar axis and the axis of declinations, and lay in the plane of pads which supported the northern hemisphere. Thus the pads of the southern hemisphere did not have to carry any load. Engineer G.V. Il'in skillfully manufactured a model (ratio 1:100) of the telescope (this is on show at the Pulkovo museum). However, the weight calculations showed that with a 6 m diameter telescope even such a rigid mounting would not be able to exclude undesirable deformations.

On November 17, 1960 at a joint session of the Astronomical Council and the Technical Council for defence equipment (State Committee of the Soviet of Ministers of the USSR), the decision was passed to concentrate on the alt-azimuth mounting, its distinctive advantage being the simplicity of construction. At this meeting B.K. Ioannisiani said, "Originally it seemed pointless to me, but the deeper we, the constructors, went into it by working through things the more we became convinced of the merits of an azimuth mounting". The virtues are:

- Stress, transmitted by the tube to the mounting and by the mounting itself to the bearings of the azimuth axis is vertical;
- the main mirror support system is simple;
- mass of the mobile parts of the telesope is essentially reducted;
- the whole construction is symmetrical;
- construction of the horizontal axis of the telescope is simple, which makes it easier to use hydrostatic bearings;
- telescope construction does not depend on the site's latitude;
- convenience of placing the secondary focus light detectors on the balconies which support the bearings of the horizontal axis.

With all its mechanical advantages an alt-azimuth mounting has shortcomings:

1. Complexity of the control system and necessity of real-time recalculation of the azimuth and zenith distance in equatorial coordinates;
2. Presence of the inaccessible region near the zenith, where the velocity and acceleration of azimuth change become extremely large;
3. Field rotation at the prime and Nasmyth foci of the telescope.

N.N. Mikhelson (1966, 1970) studied some peculiarities of the alt-azimuth mounting. He constructed graphs of isolines of the velocity and acceleration of the telescope in azimuth and zenith distance, and also for the field rotation at the prime and the two Nasmyth foci of the telescope at different points of the celestial sphere, taking into account the proper motion of the target. Conditions for observations in the near-zenith region were examined, at the points of elongation and near the pole. He studied also the influence of various inaccuracies of the mounting on the precision of the telescope pointing and tracking carried out by a star in the centre of the field and by an off-centre star. In particular, the following points were considered:

- non-perpendicularity of the vertical and horizontal axes;
- non-perpendicularity of the optical and horizontal axes;
- influence of error setting of the apparent elevation of the celestial pole;
- errors in the initial coordinates of the observed object;
- influence of errors of the zero points of the code limbs, the eccentricity of the faceplate carrying the light detector;
- flexure of the telescope's tube;
- accumulation of errors caused by discontinuity in functioning of the control computer;
- influence of astronomical refraction, differential refraction and atmospheric dispersion.

With regard to compensation for the field rotation at the prime focus of the big telescope N.N. Mikhelson (1975) believed it desireable to utilize two photoguides spaced in the field — the first is a two-coordinate, acting on the drives of the azimuth and elevation axes, the second is one-coordinate, compensating for the rotation errors of the faceplate of the primary focus. This would be an analogue of the known Ritchey (1910) cassette. The famous German scientist Küne (1971) held a similar view to this.

In 1953 N.N. Mikhelson (1965) studied the "horizontal" mounting (which subsequently received from overseas the name "alt-alt" mounting), where the yoke which supports the tube of the telescope swings around the horizontal axis. In the horizontal mounting, as distinguished from the alt-azimuth one, inaccessible regions occur at the horizon. And besides, if the yoke lies in the plane of the first vertical then the formula of coordinates' transformation is considerably simplified, facilitating the working out of the control system.

9. Design of the RM-700 telescope

The mentioned above RM-700 telescope was supplied with a metal parabolic mirror of 710 mm in diameter with a relative aperture of 1:3. Subsequently this mirror was replaced with a pyrex mirror. This metal mirror is preserved in the Pulkovo Observatory museum.

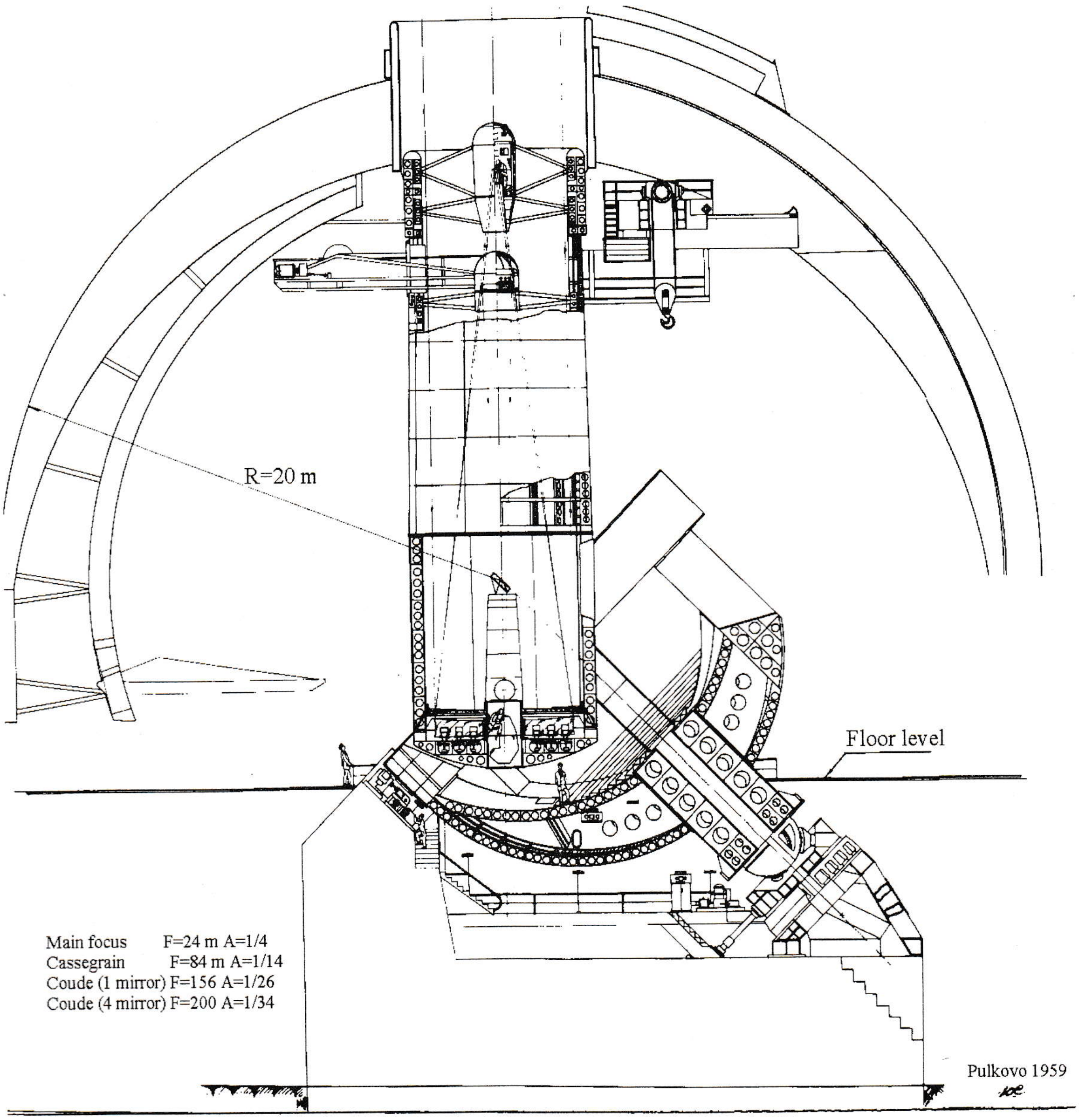


Fig 1: *Equatorial mounting of the 6 m telescope*

The optical scheme made provision for the presence of three systems: prime focus with a corrector (1:3), Cassegrain focus (1:12), and coude focus (1:28).

N.V. Merman and T.S. Belorossova, in accordance with the idea of D.D. Maksutov, calculated for the prime focus a one-lense corrector in a convergent beam in the shape of a thick afocal meniscus made of K8 glass and supplemented with a Piazzi-Smith lens of the same glass. The corrector guaranteed a relative aperture of 1:3 at the prime focus with the field $2W = 38''$.

Under the leadership of B.K. Ioannisiani a work was begun at the Design Office over the project of the RM-700 telescope. V.G. Il'in, Yu.S. Streletsky, A.V. Shumakher, I.F. Saksina, N.A. Shkutova and T.S. Gerasimova took part in this work. It was desided to use a German type equatorial. However, in order to increase the rigidity when providing for the possibility of having the coude focus, V.G. Il'in and Yu.S. Streletsky proposed some modifications. To this end the hollow polar axis was rigidly connected to the hollow declination axis (Fig.2). A second adjustable flat diagonal mirror was installed at the intersection of these axes (the first diagonal mirror at the intersection of the optical and declination axes was mounted on the devider inserted into the tube through the hole in the main mirror). The tube of the telescope was coupled rigidly with a casing rolling around the declination axis. At the place of intersection of the declination and polar axes there was an elongated cut in the casing where the latter had an especially strong system of stiffeners. The cut allowed one to point the telescope at sky areas of declinations from −20° to the pole, and shift across the world pole to declinations of +40°. Such a construction of the declination axis makes it possible (with the coude focus) to separate the bearings of the axis by a distance up to 1250 mm. This ensured a larger rigidity of all mechanical construction of the telescope. At the end of the declination axis a counterbalance and a worm gear were fixed. The motors, electrical-friction clutch and reduction gears were attached to the outer casing of the declination axis, and with inclinations of the telescope they would revolve around the immovable declination axis. A schematic of the telescope RM-700 is given in the paper by V.I. Bolshakova and N.N. Mikhelson (1965). This principle was later adopted by the Kazan Optical Works for the 450 mm reflector AЗТ-3. The polar axis drive was positioned at the base of the polar axis and contained three motors: one for rough pointing, which was coupled with the remaining part of the mechanism by an electrical-friction clutch, a synchronous clutch for hour tracking, and a motor for fine correction. To eliminate backlash the worm gear of both axes, at the suggestion of Yu.S. Streletsky (1961), were spring actuated. The motors were controlled from a push button on the telescope, from the semi-automatic and automatic control desks housed in the dome, and at the coude focus.

The tube of the telescope was solid with numerous lengthwise and circular stiffeners (designers V.G. Il'in and Yu.S. Streletsky). The cell of the main mirror was designed by A.V. Shumakher. The upper part of the tube was changeable. One ring with a spider would carry the corrector and the prime focus cassette with the focusing mechanism (designer A.V. Shumakher), the other was for detachable hyperbolic mirrors with the common electric drive for the Cassegrain and coude foci (engineer A.V. Shumakher). Special screw mechanisms to fasten the upper rings to the tube would permit one to duplicate the position of the cassette and secondary mirrors when changing from the prime focus to the Cassegrain and coude, and vice versa. This part of the telescope design was worked out by A.V. Shumakher.

The telescope was equipped with a finder and a guide. A visual tube AT used for the earth's artificial satellite observations was employed as the finder. The telescope TЭM-140 was used as the guide. The micrometer used for this was developed by A.V. Shumakher.

The telescope RM-700 (Fig.3) was built in the optical workshop of the Pulkovo Observatory under the supervision of D.S. Usanov and V.G. Shreiber by experienced engineers V.F. Burenyshev, V.Ya. Bobkov, B.V. Bryushkov-Pisarev and M.A. Malyshev, turners A.Ya. Alekseev and K.A. Khokhryakov, opticians Yu.F. Shkolnikov and K.A. Voronkov, and others. The polar and declination axes were turned on the lathe, and the units were welded and annealed at the Artillery Plant. The optics of the RM-700 were adjusted and tested by engineers G.I. Bolshakova and A.V. Shumakher (1965). The optics were adjusted by the image character and by the Hartmann method. In doing so G.I. Bolshakova paid attention to the motion of spots on the hartmannogram caused by atmospheric perturbations. Unfortunately, at that time we did not attach much importance to this phenomenon. It is currently used in adaptive optics in the method of Shak-Hartmann for restoration of the wave front disturbed by the atmoshere. In connection with this it should be mentioned that as early as 1959 academician V.P. Linnik (1959) published a proposal of using for the wave front restoration a controlled mosaic secondary mirror of a two-mirror telescope. This was a prototype of modern adaptive optics.

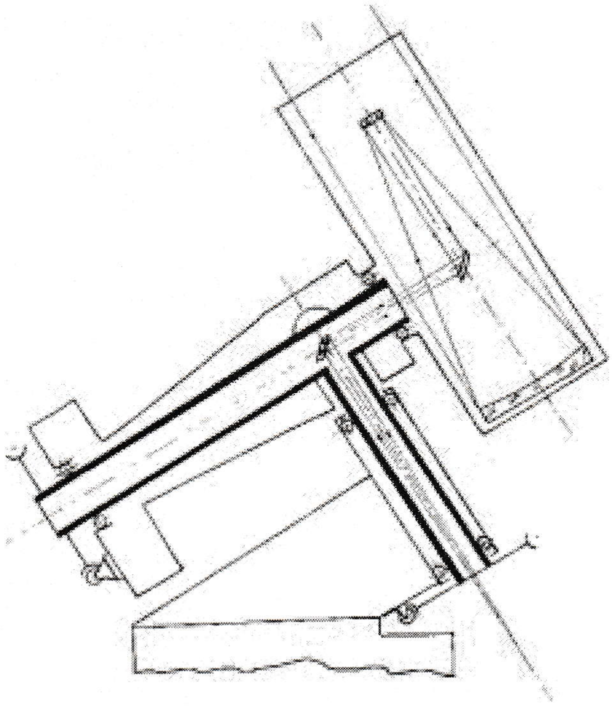


Fig. 2: *RM-700, the scheme of telescope mounting*

To study the errors of installation of the RM-700 telescope and its mounting G.I. Bolshakova and N.N. Mikhelson (1965) applied a unique method of rotating the telescope around its polar axis with the repeated photographing of the near-pole sky region.

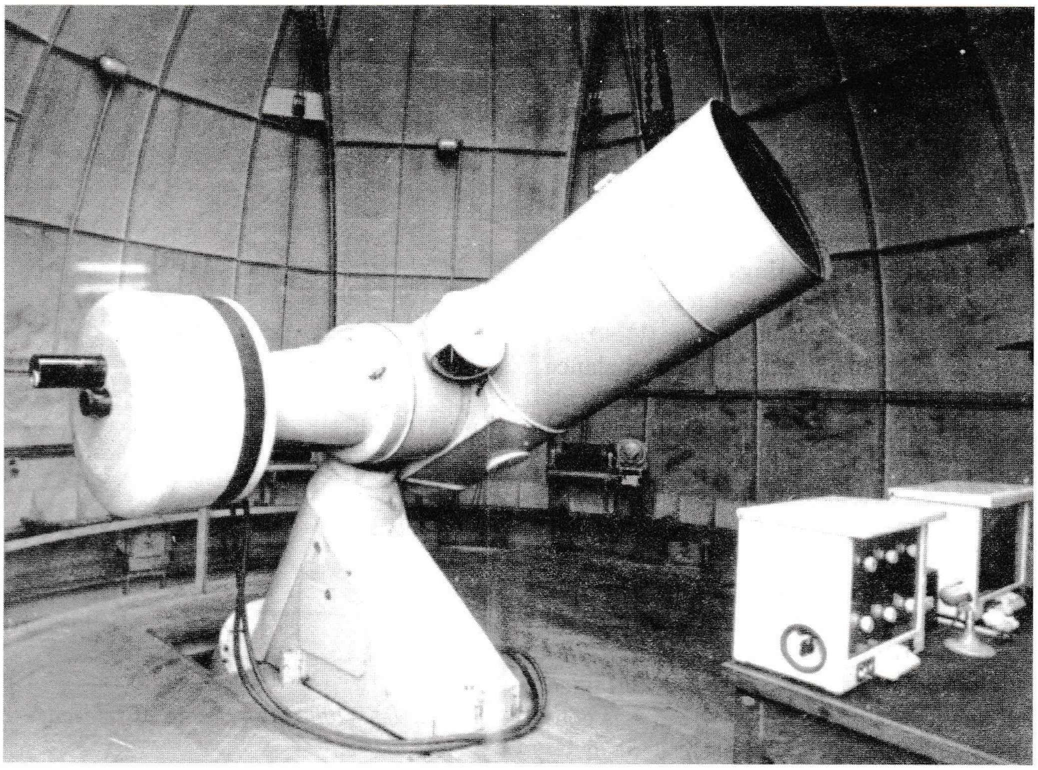


Fig. 3: *The RM-700 telescope*

10. Elaboration of the RM-700 digital control system

The very first examination of the control system for the alt-azimuth telescope revealed that no analog computing device (neither mechanical with the use of conoids, nor electro-mechanical with sine-cosine transformers – SCT) could guarantee the necessary precision of pointing and tracking (Mikhelson, 1961). The accuracy of pointing must be such that the selected guiding star appears in the field of view of the photoguide, whose angular diameter at the primary focus does not exceed 1.5 arcmin. The tracking accuracy must be such that the quality of the photoguiding would not be wasted. Academician V.P. Linnik suggested taking advantage of the new digital computers (only then being invented). This work was commissioned to N.N. Mikhelson and his group.

By 1954 there had already been a series of foreign computers and domestic МЭСМ and БЭСМ machines (developed by S.A. Lebedev) available. Although the machines were far from perfect, it was nevertheless clear that arithmetical operations, in real time, for calculating trigonometric and circular functions which were necessary for transforming the equatorial coordinates t and δ into A and z, could thus be carried out. The remaining question about the control of real instruments with the help of a computer was not clear. A trial on the real alt-azimuth telescope was premature. It was decided to use the RM-700 telescope on the equatorial mounting for this. With this object in mind engineers Yu.A. Belyaev, Z.V. Dravskikh and V.S. Sumin, and (for the last stage) K.A. Najdenova and L.V. Nikolaeva, under the supervision of N.N. Mikhelson, developed and constructed a functioning model of the electronic digital control computer (EDCC). Laboratory assistants A.V. Korolev and Yu.A. Kozlov were a great help in this work.

The control system of the RM-700 telescope included semi-automatic and automatic controls (Belyaev et al., 1963). Construction of the control desks for the semi-automatic system was completed by engineers T.S. Gerasimova and I.F. Saksina. The drives for rough and precise pointing were activated by buttons on the control desk or from a key on the telescope through a relay circuit. The automatic system included an electronic digital control device (EDCD), developed and constructed by Yu.A. Belyaev (1961), with help from A.V. Korolev and Yu.A. Kozlov.

The EDCD served for preliminary calculations of the necessary position of the telescope, for definition of its actual position, determination of the mismatch between the actual and the required position, and for its correction (Fig. 4). From the sidereal quartz clock of the accurate time service of the Pulkovo Observatory a frequency of 100 (sidereal sec)$^{-1}$ would

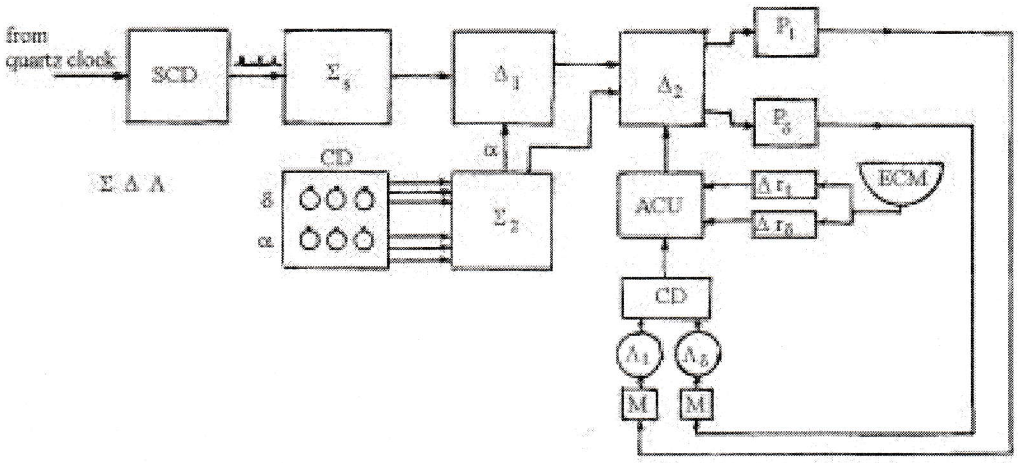


Fig. 4: *A simplified scheme of the digital control system for RM-700*

arrive at the control computer, where it was transferred by a special device for speed control (SCD) (Konshin and Mikhelson, 1961) into pulses with a frequency of 3.034074074... (sidereal sec)$^{-1}$. In observations of such mobile objects as the Moon, planets and comets the SCD would slightly change this frequency, for which a second generator of sound frequency was used. The device was designed so that the effect of errors of the sound generator's frequency instability would be diminished by a factor of 10. The impulses arriving from the SCD were scaled in the sidereal time summator generating the binary code S which corresponded to the time elapsed from the moment of the switching of the signal coming from the time service. This time interval was expressed in 1/3.034074... fractions of a sidereal sec. For the sake of convenience a special mechanism was available that would switch on time service signal once a minute. In the first arithmetic unit the code α of the preset right ascension of the object which arrived from the control desk was subtracted from the code S. This operation resulted in the hour angle code t. The second arithmetic unit served for comparing the actual position of the telescope with the required. The actual position would be determined from the code limbs attached to the axes of the telescope. 16-bit limbs were manufactured at the "Geophysics" plant and digitized by the Grey code which was transformed into the binary code by a special trigger circuit. The mechanisms of limb readout were developed by engineers Yu.N. Gel and B.N. Batanov. The control computer employed the parallel-subsequent principle and incorporated three hundred electronic bulbs. It performed computations with 18 binary bits, which corresponded to an accuracy of about 5″. The misalignment codes (on each of the coordinates) were transformed into voltage and, being amplified, then controlled the servomotors of the telescope. The transformers and amplifiers were devised by engineers K.A. Naidenova and L.V. Nikolaeva. The telescope rotation speed was determined by the mismatch value. The initial data, the right ascension α and the declination δ, were introduced into the control computer from the automatic control desk of the telescope through punched-tape coders. The automatic control desks for the control computer were worked out by N.A. Shkutova. The tube of the telescope held a unique universal coupling electromechanical counting mechanism (ECM), to the axes of which were attached sine-cosine transformers allowing the determination of the mean diffraction vector component in the equatorial coordinates. The idea of creating this device came from N.N. Mikhelson (1958, 1961), the mechanical part of it was devised by engineers B.K. Ioannisiani and A.V. Shumakher, and the electric circuits of analog-to-digital conversion were developed by engineer V.S. Sumin (1961). The lunar-planetary drive in declination was combined with the mechanism of introduction of corrections for the mean refraction in declination. This was worked out by engineer I.S. Kizelshtein, the mechanism for right ascension corrrections by I.F. Saksina.

Because the RM-700 had a unique mounting which allowed only partial shift of the telescope, and the coude focus from which the observer could not see the telescope, it was necessary to install at the coude focus a device which would show the observer the actual position of the telescope, inaccessible (for the telescope) zones of observation, and the location of the observed object in the sky. Designed by N.A. Shkutova, the construction of such a mechanism received the name "planisphere". This mechanism included a mobile stellar map, special lightings, which were supplied with colour filters and polaroids, and a projector which imitated the position of the telescope. Unfortunately trials of the "planisphere" were not carried out.

In spite of the fact that the control computer was a handicraft affair, the experience gained through its creation and trials showed the possibility of employing the digital control system with a telescope, including a big telescope on an alt-azimuth mounting.

11. Elaboration of the photoelectric guiding system, and the work of the Institute of Electromechanics and Pulkovo Observatory

The work of the Institute of Electromechanics connected with the creation of the 6 m telescope was supervised by Yu.A. Sabinin. The Institute was handed with two fundamental tasks: the first was to develop an automatic tracking system which continually corrected the work of the telescope's drive gear. In the old instruments the "guiding" of the telescope occured by hand through visual retention of a star's image on cross-hairs by the action of the so-called motors of fine correction. The first photoelectric tracking devices which received the name photoguides were used in the USA in 1930's. The guiding of a telescope with an equatorial mounting was a comparatively simple thing, as the telescope, following the star, revolved but around one axis and did so at an invariable speed. Here one only needs to correct the minor errors of the clock mechanism, gears, telescope setting, and allow for the variation of its flexure and atmospheric refraction. The problem of guiding the telescope, being alt-azimuth mounted, is much more complicated for it rotates concurrently around two axes with variable velocities and accelerations and, moreover, it has a common rotation of the field of view. The second problem consisted in developing techniques for synchronizing the rotation of the dome with the movement of the telescope. For the alt-azimuth mounting this could be solved much more easily than for the equatorial. This is because the alt-azimuth telescope and its dome rotate in one common coordinate system.

The idea of employing a photocell for tracking a star was put forward in Czechoslovakia by G. Alter (1929) in 1929 and by N.G. Ponomarev (Mikhelson, 1977) in 1941. However the first photoguide only appeared in the USA in the late 1930's. Witford and Cron (1937a,b) made a photoguide with a mirror pyramid. The star was imaged at its apex and the image was divided into four parts falling onto four photocells incorporated in pairs in a bridge circuit. The disbalances of the bridges served as signals of errors. Being amplified they were sent to the servomotors. The shortcoming of this circuit was the lack of modulation of the signal and, in connection with this, the necessity of amplifying direct voltage. In the photoguide of Babcock (1948) a star was imaged in the centre of rotation of a half-disk knife. In this case, if the image was displaced from the centre of the knife an alternating signal would then appear whose phase indicated the direction of the star's displacement, while the amplitude gave the value of the error. The shortcoming of Babcock's photoguide was the extremely primitive way of defining the phase of the signal (with the help of an electromechanical commutator).

In its first practical work the Institute of Electromechanics constructed a small Cassegrain type reflector AR-250 with a parabolic main mirror of diameter 250 mm fitted onto an alt-azimuth mounting, which was then built in the Pulkovo Observatory workshops. This work was carried out by Yu.S. Streletsky under the guidance of prof. O.A. Mel'nikov. With this telescope the colleagues of the Institute of Electromechanics I.P. Rozhnova, P.V. Nikolaev and others under the guidance of Yu.A. Sabinin (1959) tested different systems of photoelectric guiding using a photoguide of Babcock with a rotating knife-modulator of light and a light divider resembling the mirror pyramid.

The main merit of Yu.A. Sabinin's group was derived from both the working out of the construction of the new photoguides and the complexity of the approach to the solution of this task. The task was considered not only from the point of view of construction but also as scientific. It was necessary to study the influence of scintillation and image tremor on the performance of the photoguide, and select the optimum frequency of the modulations of the light flux. For the second of these it was necessary to investigate the frequency spectrum of scintillation and tremor, which was carried out by colleagues of Yu.A. Sabinin at Pulkovo and the Crimea. To this end R.G. Vinogradova (1959) developed an 8-channel frequency analyzer. P.V. Nikolaev, I.P.Rozhnova and Yu.A. Sabinin (1966) investigated statistical characteristics of stellar image fluctuations. P.V. Nikolaev (1963) carried out calculations of the influence of fluctuations on the photoguide operation, while I.P. Rozhnova (1963) worked out a photoelectric method of recording the star image tremor which, in common with P.V. Nikolaev, she employed for obtaining numerical results (Rozhnova and Sabinin, 1963). In the instrument of I.P. Rozhnova the image of a star is formed on the apex of a tetrahedral mirror pyramid, dividing the light into four parts and directing the beams to four photomultipliers. The differences of the light fluxes served as a signal of the displacement of the star's image, stimulated by its tremor. The work of the group of Pulkovo astronomers (headed by O.A. Mel'nikov) can be adjoined to this work.

For calculating the necessary field of the guide prof. O.A. Mel'nikov and his colleagues

G.G. Lengauer, K.T. Stoyanova, N.F. Kuprevich and A.N. Gerashchenko (1964) performed the work of defining the number of stars of different brightness in different areas of the sky. O.A. Mel'nikov, G.G. Lengauer and N.F. Kuprevich (1965; 1964) investigated the effects of chromatic refraction (Lengauer, 1974). They showed that it was necessary to take into account both the spectral class of the star and the spectral sensitivity of the cathode of the photomultiplier which was used in the photoguide as well.

These first photoguides were tested in the Crimean and at Pulkovo Observatories not only on the telescope AR-250 but also on the interferometer of V.P. Linnik (Sabinin and Nikolaev, 1963) which possessed alt-azimuth mounting.

Elaboration of the photoguides at the Institute of Electromechanics was used in the main to perfect the ideas of Cron and Whitford. The design of a one-coordinate photoguide of alternating current with a dihedral light-dividing prism, and a two-coordinate one with a quadrihedral pyramid (Sabinin et al., 1960) was unique. Flat mirrors direct the divided beams of light to one photomultiplier, in front of which a rotating modulator was mounted. This presented the possibility of using the amplification of the alternating current, but not of the direct current, as distinct from the photoguide of Cron with light-dividing optics.

The photoguide with a half-disk modulator was successfully tested at the Crimean Astrophysical Observatory (Sabinin and Nikolaev, 1960). It was used on the 1.22 m reflector and showed very good results with exposures up to 40 minutes on guiding by stars up to 7^m and the comet Marcos.

A review of the work of the Institute of Electromechanics on the elaboration of the photoguides was given in the book by P.V. Nikolaev and Yu.A. Sabinin (1969). Subsequently Z.N. Kuteva and R.K. Makarova (1975) worked out a photoguide with a square multiplier and electronic commutator, which divides the cycle of work into two parts: the error signal is initially determined, then the minimization of the error signal is done. The error signal is determined by the difference in the number of impulses received from the opposite sector cathodes of the photomultiplier.

Photoguides of the described types guarantee continuous correction of the telescope's position. This, though, is not necessary as errors of tracking accumulate slowly. This prompted P.V. Nikolaev to make use of the accumulation of the mismatch of the error signal. Thanks to this the limiting magnitude of the photoguide, with the half-disk modulator, was successfully enlarged by $2-3^m$ (Nikolaev et al., 1964; Burov et al., 1970; Kuteva et al., 1972; Kuteva and Sabinin, 1972). However, storage of the signal is expedient when guiding by weak objects; therefore a photoguide with variable signal storage duration was later elaborated (Nikolaev et al., 1977). This work for the BTA was already behind schedule. A.F. Burov, Z.N. Kuteva, R.K. Makarova and P.V. Nikolaev (1970) utilised the principle of photon counting when working through the photoguide, which raised the signal/noise ratio, and enhanced the sensitivity by $2-3^m$. Such a photoguide passed successful tests on the 0.4 m reflector at the Crimean Astrophysical Observatory.

All these works have practical significance for the present time. Moreover, they introduced a significant contribution to the study of terrestrial atmospheric turbulence. Subsequently the systems worked out by Yu.A. Sabinin's group laied the foundation for the automatization of many home telescopes, including the SMT reflector at the Crimean Observatory.

Yu.A. Sabinin and P.V. Egorov solved the second task — to work out a method of synchronizing the dome and the telescope movement. The first works in this direction were based on the so called "PHANTOM" model of the dome and telescope (Sabinin and Egorov, 1960). The model of the telescope, connected to the main telescope with the help of a synchro follow-up system, replicated all the movements of the telescope and rotated the model of the dome through a mechanical drive, while the model of the dome, being connected to the real dome by a similar follow-up system, made the dome turn in a desired direction. A more sophisticated system with the use of sine-cosine rotating transformers is described in (Sabinin and Egorov, 1961).

At the same time, in the capacity of a possible alternative system of control, Yu.A. Sabinin and P.V. Egorov (1963) considered an analog system of coordinate transformation (Egorov and Sabinin, 1963) with the use of CKBT. Z.N. Mamedova (1960) used CKBT for calculating the correction for the mean refraction. S.V. Korotkov, V.A. Myasnikov and Yu.A. Sabinin (1963) suggested using digital integrating systems employing digital differential analyzers.

12. Choosing the site for the telescope

New scientific results may be achieved with a big telescope if it can guarantee good image quality. This is determined not only by the quality of the optics (small residual aberration and high quality of manufacture and adjustment), mechanics and guiding system, but also by a calm atmosphere during observations. Such factors as atmospheric turbulence, transparency (of atmosphere) in a wide spectral range, number of clear nights, absence of cirrus, daily temperature gradient, wind, and other meteorological characteristics build up a concept of the "astroclimate". The spectral transparency of the atmosphere is determined by the content of dust and water vapour.

Cirrus hinder accurate photometry and large temperature drops result in the appearance of temperature gradients in a mirror body. However, for choosing the site of the new observatory a series of other factors had to be considered: the seismicity of the region, the absence (even in outlook) of sky illumination ("light pollution") from cities, factories, and mines, the presence of clean fresh water and electricity, and the possibility for transporting large non-detachable components — the main mirror of the telescope, for example, (although academician V.P. Linnik considered the possibility of using a trio of heavy-duty helicopters or an airship for this).

Attention had already been devoted to these questions by the first meeting of the country's leading astronomers on May 10, 1952, and proper attention was later shown by the Joint Council.

To carry out this work a special group was established in 1955 within Pulkovo's Astronomical Instrumentmaking Department to study the astroclimates of the USSR. It was headed by N.I. Kucherov. Under his leadership the principles of investigation and necessary apparatus were worked out. The main designers were N.I. Kucherov, Sh.P. Darchia, N.V. Bystrova, A.N. Demidov, G.Ya. Vasilyeva and L.N. Zhukova. At first the expeditions were kitted out with the above mentioned telescopes ТЭМ-140 and АТМ-140 which were produced at the Pulkovo workshops; then they received the 250 mm meniscus telescopes АЗТ-7 (produced at LOMO) which were fitted with the cassete, the electrophotometer АФМ-3 and spectrograph АСП-9 in Cassegrain focus. The suitability criterion for the site of the big telescope included the following points: the diffraction image quality of the stars, their image jitter, their flickering, the quiescence of the sun and moon's rims, the circumsolar corona, the spectral transparency of the atmosphere, and meteorological characteristics.

Many specialists were attracted to the expedition's work — scientists and laboratory assistants from Pulkovo, the other observatories in the Soviet Union, and the universities — as well as amateur astronomers from the All-Union Astronomical-Geodesical Association (AUAGA). The astronomical and meteorological observations were carried out strictly in accordance with the set of principles worked out in Pulkovo. At first star images were estimated visually via the Danjon-Couder scale (Danjon and Couder, 1935; 1940) with the help of the ТЭМ-140 and АТМ-140 telescopes and then the АЗТ-7. The seeing was estimated by the sharpness of the diffraction images, with the subsequent calculation of the angles of turbulence in the zenith. This characteristic determines the extent of disturbance of the earth's atmosphere. A little later they began the photographic recording of the traces of stars on a photoplate when a telescope is stopped. The meniscus telescopes АЗТ-7, built at LOMO, were used for this purpose. Yu.I. Beruchka (1960) developed a theory for defining the jitter of the star's image from the trace the star leaves when taking photographs while the telescope is motionless. O.B. Vasil'ev and V.V. Vyazovov (1962) created an instrument for their measurement in accordance with the idea of V.B. Sukhov. This was later improved by V.S. Sumin (Vasil'ev and Sumin, 1963). However, the results of recording are affected by the instrument's vibration, caused by the wind. To eliminate this effect N.V. Bystrova (1959, 1960) suggested mounting in front of the telescope АЗТ-7 an opaque screen with two widely spaced-out, small (60 mm) apertures with weak prisms in front of them. The prisms ensure spacing of the two images and receipt of two traces of one star, 1.2 mm apart. The vibrations of the instrument caused by the wind equally displace the two images on the plate, the atmospheric interference with the spaced-out apertures affects each of the images in its own way. For such observations N.V. Bystrova and Yu.S. Streletsky (1959) developed a special film-accessory.

The investigations of the jitter and twinkling of stars, connected in the main to elaboration of the methods of photoguiding, were also carried out by I.P. Rozhnova and R.G. Vinogradova (both of the Institute of Electromechanics) under Yu.A. Sabinin's leadership (Vinogradova, 1959; Nikolaev et al., 1966; Nikolaev, 1963; Rozhnova and Sabinin, 1963). R.G. Vinogradova (1959) investigated the frequency spectrum of twinklings and concluded that the modulation frequency of the photoguide must not exceed 100 Hz. I.P. Rozhnova (Rozhnova and Sabinin, 1963) worked out a photoelectric method of recording of the tremor of the stellar images. This was used by L.N. Zhukova (1958), A.N. Demidova and N.V. Bystrova (1960) at Pulkovo. In 1964 in Zelenchuk V.N. Frolov (1967) investigated atmospheric dispersion by a spectroscopic method, using the АЗТ-7 telescope and АСП-9 spectrograph. N.V. Bystrova and A.N. Demidova (1963) investigated the influence of atmospheric turbulence on the observation of extended celestial objects, observing both the Sun and Moon. They succeeded in elaborating a method for determining the altitude of the heterogeneous layer of the atmosphere by observation of the Sun's rim, and data about the distribution of the wind at different altitudes (Bystrova and Demidova, 1965; 1961).

On March 25, 1960 the USSR Council of Ministers, USSR, issued order No. 392-140 which urged the Pulkovo observatory to begin work on choosing the site for the telescope. The Pulkovo observatory, however, had started this work much earlier — in 1955–1956 the first expeditions had been dispatched to the regions around Stanitsa Suvorovskaya (not far from Essentuki), Anapa, and between the Volga and Don rivers. For the astroclimate investigation the services of the observatories in Tashkent, Stalinabad (Dushanbe), Ashkhabad, Shemakha, Byurakan and Abastumani were enlisted, as well as the Estonian, Leningrad, Minsk, and Simferopol branches of the AUAGA. Over eighty people simultaneously took part in the various survey groups.

In 1955 the sites between the rivers Volga and Don, round the cities Essentuki and Anapa were inspected by G.I. Bol'shakova, A.N. Kozyrev, A.Ph. Sukhonos (Demidova et al., 1959; Vasil'eva, 1959). Later expeditions worked in Azerbaijan (G.V. Akhundova and S.I. Sorin) (Akhundova and Darchiya, 1961; Akhundova and Aliev, 1961; Akhundova, 1963); in Armeniya near mountains Garni and Dara M.P. Platonova, N.A. and A.I. Shakht, V.A. Naumov, R.N. Ikhsanov worked (Bol'shakova et al., 1967); in Georgia near Atotsi and Tsitsisdzhvari — K. Ehehrme, V. Tujsk, T.Ph. Vijk, N.A. Boshnyakovich, N.V. Bystrova and others (Bol'shakova et al., 1967; Boshnyakovich et al., 1962); in Dagestan near Tsuvar, Vikhli and on mountain Turchidag — G.I. Bolshakova, N.M. Bronnikova, A.Ph. Sukhonos, Yu.I. Beruchka, A.Kh. Darchiya, Sh.P. Darchiya, A.A. Efimov, N.A. Shakht, and others (Darchiya and Darchiya, 1959; Bolshakova et al., 1967; Bonyashkovich et al., 1962; Darchiya et al., 1967; Darchiya, 1961); in the mountain astronomical station of the Main Astrophysical Observatory near Kislovodsk — L.N. Zhukova, V.V. Makarova, L.F. Chmil' (Darchiya and Darchiya, 1959; Bolshakova et al., 1967; Bronnikova, 1963; Vasil'yanovskaya, 1963); in Krasnodar region near settlement Botanika — O.B. Vasil'ev, V.V. Vyazovov (Korotkov et al., 1963; Vasil'ev and Vyazovov, 1962); in the sites of Zelenchuk (Fig. 5) — O.B. Vasil'ev and others (Vasil'ev and Nelyubin, 1968; Vasil'ev and Frolov, 1965); on the Pamirs in Chechekty and Khodzha-Obi-Garm O.P. Vasil'yanovskaya, A.Kh. Kurmaeva, A.S. and S.I. Bulanovs worked (Vasil'yanovskaya, 1963; Kurmaeva, 1971; Kurmaeva and Darchiya, 1963); in the region of lake Issyk-Kul' — G.I. Plyugin, V.N. Frolov, L.F. Chmil', V.A. Varina, and S.A. Murri (Plyugin and Frolov, 1966).

From 1960 to 1962 sixteen expeditions concurrently surveyed the territiory from the Crimea to the Pacific Ocean, including the regions round Ussurijsk (expedition of Leningrad AUAGA) and on the Pamirs in the region of Murgab. Six points were picked out: Chechekty (Pamirs), Dzhety-Oguz (Kirghizia), Iskander-Kul' and Sanglok (Tajikistan), the Mountain Astronomical Station (MAS) of the Pulkovo Observatory near Kislovodsk, and Zelenchukskaya.

In 1961 investigations were carried out at eight points round Zelenchukskaya and the MAS. From 1961 to 1962 the work was continued on the north-west spurs of the Main Caucasian Range (Marukha, Dzhissa, Chapal, mountain Pastukhova-Semirodnicki), and in Tajikistan (Iskander-Kul', Sanglok, Chechekty, Khodzha-Obi-Garma) (Demidova et al., 1971). In 1962 the east coast of the Crimea from Sudak to Alushta was inspected by Bol'shakova and Demidova (1975), A.F. Sukhonos and M.M. Gnevyshev.

As well as by the expeditions, observations were also carried out at Pulkovo (chiefly by N.V. Bystrova, A.N. Demidova (Bystrova, 1959; 1960; Bystrova and Demidova, 1963, 1961, 1965, Demidova, 1960), and L.N. Zhukova (1959). These were aimed at developing and testing new methods, instructions, and means for standardizing the observations.

A comparison of the results taken from Febuary 1, 1962 to June 30, 1962 in Zelenchukskaya and the Crimea showed that the mean angle of turbulence at all zenith distances upto $z = 70°$ in Zelenchukskaya is roughly twice less than in the Crimea, but that the nightly temperature variations in the Crimea are smaller. Other conditions (number of clear nights, wind, humidity etc.) were approximately equal.

With calculation of all the above enumerated descriptions the result of the first stage of inspections was a preference for the Northern Caucasus region. Although the astroclimate of the East Pamirs (Chechekta) proved better than all the other investigated places, the remoteness, altititude (4000 m), absence of good roads, and seismicity of the region obliged its rejection. The second stage showed the advantage of the Zelenchukskaya district in the Karachai-Circassia Autonomous Region, where the work continued in 1963.

The principal results of expeditionary investigations of the astroclimate were discussed at four meetings of the Joint Council for the BTA, at a meeting with the president of the USSR AS, M.V. Keldysh, (June 17, 1961), and at conferences of the "Commission of the Astronomical Council for Optical Instability of the Earth's Atmosphere" in Moscow, 1958, and Kiev, 1963.

On May 22, 1962, the Joint Council accepted the decision to recommend as the site of the telescope post No 4 in the Semirodniki region (height 2100–2300 m above sea level). The decision concerning the chosen site was ratified by the president of the Academy of Sciences, M.V. Keldish, by order No 783, on March 15, 1963. On July 5, 1963 an order No 40-955 was issued concerning the allocation of a land strip in the Zelenchukskaya district. The commission appointed for this purpose was instructed to choose a site for construction of the settlement and observatory, and clarify construction of the road. The chairman of this commission was A.A. Mikhajlov, and the commission members were O.A. Melnikov and N.I. Kucherov (astronomers), I.A. Ostanin and

Fig 5: *Searching for the 6 m telescope site*

D.Kh. Yenikeyev (representatives of the Leningrad Department of the Scientific Research Institute of Design), K.N. Chernopyatov (member of the Presidium AS), and others. Nizhnij Arkhyz was chosen for the laboratory building and residential settlement, not far from Stanitsa Zelenchukskaya (1100 m above sea level), and the spurs of the mountain "Pastukhova" as the site of the telescope, at an altitude of 2100 m. Expeditional work in the Zelenchuk district continued in 1963.

Unfortunately the expeditional work did not pass without tragedy. In 1960 on the rockface of Storozhevskaya Skala mountain, not far from Zelenchukskaya, a member of AUAGU and war-veteran N.N. Sklyarov was killed by a bolt of lightning.

The results of the astroclimate study were used not only for choosing the site of the telescope but also for more general investigations. Thus G.I. Bolshakova and Sh.P. Darchiya (1965) studied variations of turbulence angle, and by examining the series of observations from 1955 to 1962 at a number of places, investigated the constancy of astroclimate (Bolshakova and Darchiya, 1965). O.B. Vasil'ev (1965) scrutinized the dependence of stars' image flickering on zenith distance. Together with N.F. Nelubin O.B. Vasiljev (1970, 1971, 1972) examined the dependence of the seeing on meteorological characteristics, and with N.N. Yakovleva (Vasil'ev and Yakovleva, 1971) he examined relation between the astroclimate and altitude (above sea level) of the observational site. L.K. Zinchenko (1965) investigated the relation between seeing and fluctuations of temperature and wind.

The organization of expeditions, matters of theory, methods of investigation, and the numerous results of observations were summarised in a series of works by N.I. Kucherov (1965, 1959, 1962) and Sh.P. Darchiya (Darchiya et al., 1967; Darchiya, 1961; Darchiya, 1985, 1963, Afanasieva et al., 1964).

Not only atmospheric turbulence affects image quality taken with a telescope. The turbulence of air inside a dome, caused by sources of heat (electric motors, and other electric machines and instruments) and the flow of air round the dome, present problems. The latter were investigated by A.S. Zherbina together with R.A. Petrova. For this purpose an aerodynamical tube was built (at Pulkovo) with a section of working chamber about 400 × 400 mm, in which a line of dome models were blown on. The observations were carried out with the help of two tubes ИАБ-451, the former worked as a collimator, the latter as a telescope for observations. A neon laser was used as a light source.

13. Drawing up of technical tasks

In November 1960, at the meeting of the Astronomical Council of USSR AS and the Joint Council the advanced project of BTA with altazimuth mounting was discussed and approved.

D.D. Maksutov, N.N. Mikhelson, O.A. Mel'nikov and G.G. Lengauer drew up a draft technical task for the big telescope. This was discussed and clarified on more than one occasion.

On January 11, 1961 a meeting attended by representatives of LOMO, the State Institute of Optics and the Institute of Automation and Telemechanics took place at Pulkovo, at which the technical tasks for the telescope's control system were discussed. It was considered possible to use local photoelectric guiding (namely, accurate guiding not with the whole telescope but with a detector or devices mounted in front of it), to admit an error of guiding by EDCD 7″ of a big circle in any direction, and also to consider it necessary to ensure the accuracy of the photoguide's performance not worse than 0.2 of the apparent diameter of a star's image (for a diameter not less than 2″). The speed of tracking artificial celestial bodies must not exceed 5 times that of apparent motion of the Moon among stars. At this meeting the allowances for the image quality produced by the telescope's optics were established: for each aberration (coma, astigmatism and spherical) not more than 10 μ m, and for the radius of the chromatic circle within the limits of 4000 Å to 6600 Å — 15 μm.

On January 20 and 21, 1963 the discussions continued. The drawn-up project was taken as the foundation of the final technical task (TT), elaborated jointly by the Pulkovo Observatory and LOMO. Profs. O.A. Mel'nikov and N.A. Kozyrev drew up the TT for the spectral devices of the telescope. It was envisaged to build four spectrographs — one, fast, for the main focus, and three for the two Nasmyth foci. The spectrograph of the main focus was ear-marked, chiefly, for investigating spectra of nebulae in the 3000–12000 ÅÅ range. It is furnished with a mirror collimator, three changeable diffraction gratings, and four changeable cameras of type Schmidt-Cassegrain with external focus. The main stellar spectrograph was mounted on one of the balconies of the Nasmyth focus for investigation of faint stars with a working range of 3000–11000 ÅÅ. It proposed to have a mirror collimator of 300 mm in diameter and a focus of about 8 m, two diffraction gratings, and three cameras with focal distances of 3000, 600, and 200 mm, which provide a dispersions from 1.3 to 55 Å/mm. The echelle and planetary spectrographs are mounted on the second balcony at the Nasmyth focus. The echelle spectrograph, with two changeable echelles, working in high orders of the spectrum (from 11 to 25), embraces the region of the spectrum from 10300 Å to 3320 Å and provides a dispersion from 25 Å/mm to 70 Å/mm. The planetary spectrogrpah (the TT for this was elaborated by N.A. Kozyrev) has three changeable diffraction gratings and works in the region of 3000–1000 ÅÅ with a dispersion from 5 to 50 Å/mm. It can either directly record spectra on the photographic plate or do so with the help of an image tube (IT). V.E. Moroz (SAI) drew up the TTs for infra-red spectrometer and photometer. These devices were designed at the State Institute of Optics (SIO) and at LOMO.

O.A. Mel'nikov, G.G. Lengauer and V.S. Popov developed the TT for the dome of the telescope and the observatory itself. On July 17, 1964 this task was discussed at a meeting of the presidium of the Joint Council. Under the leadership of its director E.A. Ostanin, and chief architect D.Kh. Enikeyev the Leningrad department of the Scientific Research Institute of Design designed the telescope dome and entire observatory complex (Enikeev, 1978). The dome was planned by the "Stalkonstruktsiya" trust under M.Ya. Vishnevskij's (1969, 1977) guidance. The intricate mechanisms of the dome necessary for its opening, rotation, the hoisting of wind-protection blinds, and the displacement of the crane inside the dome, were designed by the Leningrad Department of the "Soyuzprommekhanizatsiya" trust (chief designer A.P. Eliseev).

The project for the Special Astrophysical Obsevatory was discussed at three meetings of the Joint Council and at the presidium of the Astronomers Council. Individual technical questions were repeatedly discussed at Pulkovo, the Leningrad department of the Scientific Research Institute of Design and the "Soyuzprommekhanizatsiya" and "Yuzhstalconstruktsiya" trusts.

D.D. Maksutov and V.V. Oshchurko (LOMO) drew up the TT for a unique machine-tool for the polishing of the 6 m telescope, and a workshop for its finishing and testing. This machine tool was manufactured at the Kolomensk Factory of Heavy Machine-tool Engineering and installed at the Lytkarino Factory of Optical Glass in a specially-built workshop. During this work D.D. Maksutov constantly advised these factories.

Composed technical tasks and scientific-technical accounts were transmitted from the Pulkovo Observatory to the factories of LOMO, Lytkarino and Leningrad Department of the Scientific Research Institute of Design.

On January 10, 1964 the head of the Central Design Office of LOMO, R.M. Kasherininov, acknowledged by letter receipt from the Pulkovo observatory of the TT for the construction of the telescope (N.N. Mikhelson) and spectral devices (O.A. Mel'nikov, N.A. Kozyrev, V.P. Linnik), the account of the investigation into the deformations of the main mirror by the modelling method (E.G. Grossvald), the calculation of the compensating circuit of the BTA main mirror investigation (D.D. Maksutov), the programmes for the operation of the DECC (N.N. Mikhelson), and the data for the theory of alt-azimuth mounting (N.N. Mikhelson).

14. Conclusion

Everything received at Pulkovo and the other adjoining institutes and organisations, as well as the developed technical tasks, were used by LOMO, SOI, the Lytkarino Factory of Optical Glass, the Leningrad Department of the Scientific Research Institute of Design, and other organisations for bring into being the largest contemporary telescope in the world (6 m), and the Special Astrophysical Observatory. Sternberg Astronomical Institute took the data from the results of the astroclimate study for the Sanglok region. The Leningrad State University Astrophysical Observatory used the methods of the study of astrophysical mirror deformations.

What was the upshots of the Pulkovo Observatory and the Institute of Electromechanics contribution in the 6 m telescope BTA creation? They are as follows:

1. Calculation of the telescope's optics and perfection of the methods of its control.
2. Cultivation of the theory of the alt-azimuth mounting of a telescope, and the theory of its inaccuracies.
3. Proof of the possibility of using electronic digital techniques for control of the telescope.
4. Experimental investigations of the deformation of the main and secondary mirrors of the telescope.
5. Perfection of the photoelectric guiding system of the telescope and work related to this on the astroclimate and choice of stars for guiding.
6. Complex investigation of the astroclimate (USSR), establishing a relation between seeing and meteorological characteristics; the working out of appropriate methods and apparatus.
7. Drawing up of scientifically-founded technical tasks for the optics, mechanics, telescope control system, light detectors, housing, dome, and for the observatory itself.

It is worth noting, that at the present time all large telescopes in the world are placed on alt-azimuth mountings and furnished with electronic control systems. This was initiated from the outset by the Pulkovo obervatory. From the first third of the 1960's the main work on the BTA moved from the research institutes of the Academy of Sciences (Pulkovo Observatory, Institute of Automation and Telemechanics) into industry. LOMO, the Lytkarino Factory of Optical Glass, CCB-34 and other adjoining industrial enterprises were then involved in this work. On June 9, 1963 a joint session of the Scientific-Technical Council of LOMO and Joint Council for the BTA took place at LOMO. At this meeting the presentation of the draft technical project of the telescope was passed.

D.D. Maksutov, O.A. Mel'nikov and N.N. Mikhelson continued to give constant consultative help to LOMO, Leningrad department of the Scientific Research Institute of Design and the Lytkarino factory.

To find out more about the work of LOMO consult the papers of B.K. Ioannisiani (1971, 1976, 1977), Ioannisiani et al. (1972), Ioannisiani and Neplokhov (1979), A.M. Buzhinsky and colleagues (Buzhinsky et al., 1976a,b; Shestakov et al., 1977; Buzhinsky et al., 1978a,b), the series of papers in the journal "Optical-mechanical industry", 1976–80, "Izvestiya of SAO", 1971–1973, and the brochure "Creation of the Big Alt-azimuth Telescope BTA" (editor V.Yu. Torochkov, 1976), in which, incidentally, the role of the Academy of Sciences is rarely mentioned.

In December 1974 the 6 m telescope (BTA) was accepted for provisional operation.

Список литературы

Afanasieva E.M., Darchia Sh.P., Esikov N.P. et al., 1964, Catalogue of astroclimatic characteristics for 1953, Novosibirsk, **1**, 71

Akhundova G.V., Darchia Sh.P., 1961, Izvestiya of Azerb. AS, Ser. fiz.mat. **1**, 167

Akhundova G.V., Aliev A.A., 1961, Izvestiya of Azerb. AS, Ser. fiz.mat. **6**, 165

Akhundova G.V., 1963, in: Optical instability of the Earth's atmosphere, M.-L., 91

Alter G., 1929, Zts. Instrumenkunde, **49**, No. 11, 553

Babcock H.W., 1948, Astrophys. J., **107**, No. 1, 73

Belorossova T.S., Maksutov D.D., Merman N.V., Sosnina M.A., 1964, Izvestiya MAO, **175**, 162

Belorossova T.S., Maksutov D.D., Merman N.V., Sosnina M.A., 1961, Izvestiya MAO, **169**, 114

Belorossova T.S., Merman N.V., 1968, Izvestiya MAO, **184**, 142

Belorossova T.S., Merman N.V., Sosnina M.A., 1975, Izvestiya MAO, **193**, 175

Belyaev Yu.A., Gerasimova T.S., Dravskikh Z.V., Mikhelson N.N., Sumin V.S., Shkutova N.A., Shumakher A.V., 1963, Novaya Tekhnika v Astronomii, 23

Belyaev Yu.A., 1961, Izvestiya MAO, **169**, 171

Beruchka Yu.I., 1960, Izvestiya MAO, **165**, 30

Bolshakova G.I., Bronnikova N.M., Vijk T.F., Demidova A.N., Zhukova L.N., Sukhonos A.F., Shakht N.A., 1967. Izvestiya MAO, **182**, 255

Bolshakova G.I., Darchia Sh.P., 1964, Izvestiya MAO, **175**, 155

Bolshakova G.I., Darchia Sh.P., 1965, in: Optical instability of the Earth's atmosphere, M.-L., 68

Bolshakova G.I., Mikhelson N.N., 1965, Novaya Tekhnika v Astronomii, M.-L., Nauka, **2**, 28

Bolshakova G.I., Shumakher A.V., 1965, Novaya Tekhnika v Astronomii, M.-L., Nauka, **2**, 25

Boshnyakovich N.A., Bystrova N.V., Demidova A.N., Zhukova L.N., Kasinskij V.V., Ehrme K.A., 1962, Izvestiya MAO, **170**, 155

Bronnikova N.M., 1963, in: Optical instability of the Earth's atmosphere, M.-L., 116

Budnikova T.V., Fridman V.M., 1964, Izvestiya MAO, **177**, 119
Burov A.F., Kuteva Z.N., Nikolaev P.V., Makarova R.K., 1970, Izvestiya KrAO, **41**, 412
Burov A.F., Kuteva Z.N., Makarova R.K., Nikolaev P.V., 1970, **3**, 103
Buzhinskij I.M., Koryagina E.I., Dmitrieva Z.P., 1976, Optiko-Mekh. Prom., **11**, 34
Buzhinskij I.M., Vil'ner D.E., Stepanov S.E., 1978, Otiko-Mekh. Prom., **1**, 23
Buzhinskij I.M., Dmitrieva Z.P., Aref'eva K.I., 1978, Otiko-Mekh. Prom., **5**, 37
Bystrova N.V., 1959, Proceed. on study of stellar scintillation, M.-L., 155
Bystrova N.V., 1960, Izvestiya MAO, **165**, 38
Bystrova N.V., Demidova A.N., 1961, Izvestiya MAO, **169**, 152
Bystrova N.V., Demidova A.N., 1965, in: Optical instability of the Earth's atmosphere, M.-L., 30
Bystrova N.V., Streletskij Yu.S., 1959, Proceed. on study of stellar scintillation, M.-L., 246
Chernina V.S., 1964, Izvestiya MAO, **177**, 125
Couder A., 1953, Publ. Obs. Houte Provence, **2**, No. 53, 1
Danjon A., Couder A., 1935, Lunettes et Telescopes, Paris, Ed. de la Rev. d'Opt. Theor. et Instrum. 715
Danjon A., Coude A., 1940, Astron. Zh., **17**, 77
Darchia Sh.P., 1961, Izvestiya MAO, **169**, 99
Darchia Sh.P., 1963, in Optical instability of the Earth's atmosphere, M.-L., 83
Darchia Sh.P., 1985, About astronomical climate in the USSR, M., Nauka, 175
Darchia A.Kh., Chmil' L.F., Darchia Sh.P., 1964, Izvestiya MAO, **165**, 52
Darchia A.Kh., Darchia Sh.P., 1959, Proceed. on study of stellar scintillation, M.-L., 202
Darchia Sh.P., Esikov N.P., Kuznetsova L.Kh. et al., 1967, Catalogue of astroclimatic characteristics for 1954-1961, Ed.: Stepanov V.E., Irkutsk, **2**, 318
Demidova A.N., Bronnikova N.M., Vasil'eva G.Ya., 1959, Proceed. on study of stellar scintillation, M.-L., 131
Demidova A.N., Bystrova N.V., 1960, Izvestiya MAO, **165**, 12
Egorov V.P., Sabinin Yu.A., 1963, Novaya Tekhnika v Astronomii, 52
Enikeev D.Kh., 1978, in: Projects of SRI and special laboratories of large scientific complexes, M., Nauka, 62
Fridman V.M., 1964, Izvestiya MAO, **177**, 138
Frolov V.N., 1967, Izvestiya MAO, **182**, 250
Golovanova T.N., Mench K.L., 1956, Pribory, tekhnika, eksperimenty, **1**, No. 1, 81
Goreva G.I., Sabinin Yu.A., Nikolaev P.V., Shumakher A.V., 1963, Novaya Tekhnika v Astronomii, 80
Grossvald E.G., 1961, Izvestiya MAI, **169**, 162
Grossvald E.G., 1967, Izvestiya MAO, **182**, 269
Grossvald E.G., Tavastsherna K.G., 1965, Novaya Tekhnika v Astronomii, **2**, 31
Grossvald E.G., Tavastsherna K.G., 1966, Izvestiya MAO, **180**, 184
Ioannisiani B.K., 1970, Novaya Tekhnika v Astronomii, **3**, 5
Ioannisiani B.K., 1971, Astrofiz. Issled. (Izv. SAO), **3**, 3
Ioannisiani B.K., 1976, Optiko-Mekh. Prom., **7**, 25
Ioannisiani B.K., 1977, Sky and Telescopes, **54**, 356
Ioannisiani B.K., Malarev V.A., Neplokhov E.M., Pavlov V.N., 1972, Novaya Tekhnika v Astronomii, **4**, 22
Ioannisiani B.K., Neplokhov E.M., 1979, Novaya Tekhnika v Astronomii, **6**, 12
Konshin V.M., Mikhelson N.N., 1961, Izvestiya MAO, **169**, 158
Korotkov S.V., Myasnikov V.A., Sabinin Yu.A., 1963, Novaya Tekhnika v Astronomii, 60
Kucherov N.I., 1959, Proceed. on study of stellar scintillation, M.-L., 183
Kucherov N.I., 1962, Astroclimate, M. Znanie, 38
Kucherov N.I., 1965, in: Optical instability of the Earth's atmosphere, M.-L., 49
Kuhne C., 1971, Large Telescope Design, Geneva, March 1-5, 453
Kurmaeva A.Kh., 1971, Izvestiya MAO, **186**, 192
Kurmaeva A.Kh. Darchia Sh.P., 1963, in: Optical instability of the Earth's atmosphere, M.-L., 107
Kuteva Z.N., Makarova R.K., 1975, Novaya Tekhnika v Astronomii, **5**, 144
Kuteva Z.N., Sabinin Yu.A., Nikolaev P.V., 1972, Novaya Tekhnika v Astronomii, **4**, 18
Kuteva Z.N., Sabinin Yu.A., 1972, Izvestiya KrAO, **45**, 196
Lengauer G.G., 1974, Izvestiya MAO, **192**, 138
Linnik V.P., 1959, Proceed. on study of stellar scintillation, M.-L., 228
Lobachev M.V., Yakukhnova L.E., 1977, Astrofiz.Issled. (Izv. SAO), **9**, 99
Loretsyan Zh.M., 1967, Soobshch. Byurak. Obs., **38**, 58
Loretsyan Zh.M., 1967, Soobshch. Byurak. Obs., **38**, 66
Loretsyan Zh.M., 1967, Soobshch. Byurak. Obs., **38**, 72
Maksutov D.D., 1932, Anaberration reflecting surfaces and systems and their new ways of testings, Trudy State Optical Inst., **8**, vyp. 86, 120
Maksutov D.D., 1937, Optiko-Mekh. Prom., **3**, 1
Maksutov D.D., 1948, in Manufacture and study of astronomical optics, M.-L. 280, 2nd edition: 1984, Nauka, M. 272
Maksutov D.D. , 1957, Izvestiya MAO, **160**, 5
Mamedova Z.N., 1960, Izvestiya KrAO, **24**, 220
Melnikov O.A., Lengauer G.G., Stoyanova K.T., Gerashchenko A.N., 1964, Izvestiya MAO, **177**, 81
Melnikov O.A., Lengauer G.G., Kuprevich N.F., 1964, Izvestiya MAO, **175**, 121
Melnikov O.A., Lengauer G.G., Kuprevich N.F., 1965, in: Optical instability of the Earth's atmosphere, 5
Melnikov O.A., Lengauer G.G., Kuprevich N.F., 1964, Izvestiya MAO, **175**, 121
Merman N.V., 1958, Izvestiya MAO, **159**, 144
Merman N.V., 1958, Izvestiya MAO, **159**, 144
Merman N.V., Sosnina M.A., 1965, Izvestiya MAO, **178**, 214
Mikhelson N.N., 1958, Izvestiya MAO, **162**, 153
Mikhelson N.N., 1958, Izvestiya MAO, **169**, 131
Mikhelson N.N., 1958, Izvestiya MAO, **162**, 149
Mikhelson N.N., 1961, Izvestiya MAO, **169**, 141
Mikhelson N.N., 1961, Izvestiya MAO, **169**, 167
Mikhelson N.N., 1965, Novaya Tekhnika v Astronomii, **2**, 34

Mikhelson N.N., 1966, Izvestiya MAO, **181**, 23
Mikhelson N.N., 1970, Izvestiya MAO, **185**, 279
Mikhelson N.N., 1975, Astrofiz. Issled. (Izv. SAO), **7**, 237
Mikhelson N.N., 1977, in: Problems of observational and theoretical astronomy, ser. Problems of study of the Universe, LOVAGO USSRAS, M.-L., 136
Mintz L.J., Jackson B.W., 1969, IEEE Trans. on Aerosp. and Electronic Systems, March, AES-5, No. 2, 253
Newcomb S., 1903, The reminiscence of an astronomer, London-New-York, Harper, 424
Nikolaev P.V., Rozhnova I.P., Sabinin Yu.A., 1964, Izvestiya KrAO, **32**, 173
Nikolaev P.V., Rozhnova I.P., Sabinin Yu.A., 1966, Izv. KrAO, **35**, 295
Nikolaev P.V., Sabinin Yu.A., 1969, in: Fotoelectric sledyashchie Sistemy, L.: Energiya, 132
Nikolaev P.V. 1963, in: Optical instability of Earth's atmosphere, 150
Nikolaev P.V., Sabinin Yu.A., Tyukin V.N., 1977, Izvestiya KrAO, **56**, 138
Pal'mov V.A., Pupyrev V.A., 1964, Izvestiya MAO, **177**, 145
Pan'Tszyun'-Hua, 1961, Izvestiya MAO, **169**, 123
Pan'Tszyun'-Hua, 1960, Izvestiya MAO, **165**, 152
Ritchey G.W., 1910, Astrophys. J., **32**, 26
Rozhnova I.P., Sabinin Yu.A., 1963, Novaya Tekhnika v Astronomii, 91
Rozhnova I.P., Sabinin Yu.A., 1963, in: Optical instability of the Earth's atmosphere, 138
Sabinin Yu.A., 1959, Proceed. on study of stellar scintillation, M.-L., 232
Sabinin Yu.A., Belyaev E.N., Myasnikov V.A., 1960, Izvestiya KrAO, **23**, 174
Sabinin Yu.A., Egorov P.V., 1960, Izvestiya KrAO, **22**, 275
Sabinin Yu.A., Egorov V.P., 1961, Izvestiya KrAO, **26**, 395
Sabinin Yu.A., Egorov V.P., 1963, Novaya Tekhnika v Astronomii, 37
Sabinin Yu.A., Nikolaev P.V., 1960, Izvestiya KrAO, **24**, 203
Sabinin Yu.A., Nikolaev P.V., 1963, Novaya Tekhnika v Astronomii, 23
Sabinin Yu.A., Belyaev E.N., Myasnikov V.A., 1960, Izvestiya KrAO, **23**, 174
Sabinin Yu.A., Nikolaev P.V., 1960, Izvestiya KrAO, **24**, 203
Shestakov V.A., Stepanov S.E., Buzhinskij I.M., Sinyakov V.F., 1977, Optiko-Mekh. Prom., **3**, 55
Sosnina M.A., 1958, Izvestiya MAO, **162**, 137
Sosnina M.A., 1968, Izvestiya MAO, **184**, 135
Streletskij Yu.S., 1961, Inventor's certificate, USSR, Cl.42h, 10_{03}, No. 135665, Bull. Izobret. **No. 3**
Sumin V.S., 1961, Izvestiya MAO, **169**, 152
Vasil'yanovskaya O.P., 1963, in: Optical instability of the Earth's atmosphere, L., 97
Vasil'ev O.B., 1965, in: Optical instability of the Earth's atmosphere, M.-L., 40
Vasil'ev O.B., Frolov V.N., 1965, Izvestiya MAO, **178**, 207
Vasil'ev O.B., Nelyubin N.F., 1968, Soobshch. SAO, **1**, 3
Vasil'ev O.B., Nelyubin N.F., 1970, Astrofiz. Issled. (Izv. SAO), **1**, 125
Vasil'ev O.B., Nelyubin N.F., 1970, Astrofiz. Issled. (Izv. SAO), **2**, 185
Vasil'ev O.B., Nelyubin N.F., 1971, Astrofiz. Issled. (Izv. SAO), **3**, 26
Vasil'ev O.B., Sumin V.S., 1963, in: Optical instability of the Earth's atmosphere, M.-L., 163
Vasil'ev O.B., Vyazovov V.V., 1962, Izvestiya MAO, **170**, 144
Vasil'ev O.B., Yakovleva N.N., 1970, Astrofiz. Issled. (Izv. SAO), **1**, 100
Vasil'eva G.Ya., 1959, Proceed. on study of stellar scintillation, M.-L., 165
Vestnik USSR AS, 1958, About works on creation of big telescopes, Vestnik of USSR AS, **3**, 106
Vinogradova R.G., 1959, Proceed. on study of stellar scintillation, M.-L., 135
Vishnevskij M.Ya., Polushin A.P., Tolstobrov G.M., 1969, in: Industrial Engineering, **6**, 26
Vishnevskij M.Ya., Polushin A.P., Tolstobrov G.M., 1977, Proceed. SRI, **21**, 128
Whitford A.E., Kron G.E., 1937, Photoelectric Guiding of Astronomical Telescopes, Review Sci. Instruments, **8**, No. 3, 78
Whitford A.E., Kron G.E., 1937, J. British Astron. Assoc., **47**, 275
Zherbina A.G., 1968, Izvestiya MAO, **184**, 193
Zhukova L.N., 1958. Izvestiya MAO, **162**, 72
Zinchenko L.K., 1965, in: Optical instability of the Earth's atmosphere. M.-L., 60