Scientific session of the Division of General Physics and Astronomy of the Academy of Sciences of the USSR (22 March 1989)

Usp. Fiz. Nauk **158**, 531–533 (July 1989)

A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on 22 March, 1989 at the S.I. Vavilov Institute of Physics Problems of the USSR Academy of Sciences. The following two reports were presented at the session:

1. *I.L. Landau*. Condensation of cold atoms and new amorphous states of metals.

2. *O.I. Bugaenko, S.M. Kudryavtsev, V.V. Nesterov, S.B. Novikov, and Yu.A. Shokin*. High precision position observations of Phobos on Maĭdanak mountain in 1988.

A brief summary of one of the papers is given below.

O.I. Bugaenko, S.M. Kudryavtsev, V.V. Nesterov, S.B. Novikov, and Yu.A. Shokin. *High precision position observations of Phobos on Maĭdanak mountain in 1988.* The complexity of position observations of Martian satellites is due to the closeness of their orbits to the surface of Mars whose total brightness exceeds that of the satellites by six orders of magnitude. A considerable part of the visible orbit of Phobos is situated within the strong halo illumination from Mars due to the unavoidable diffraction at the entrance aperture of the telescope and different kinds of light scattering in the optical path. Therefore by the end of 1986 only 2902 earth-based coordinate measurements of Phobos were known (measurements along each of the coordinates are regarded as independent measurements) with an average r.m.s. error of 0″.41 which could be utilized for improving the orbits.[1] A few measurements made from the spacecraft "Mariner-9" and "Viking-1, -2" had an accuracy on the average of almost an order of magnitude better, but a systematic discrepancy was found to exist with the earth-based observations of Phobos.

In the space mission of the "Phobos" spacecraft, the carrying out of the planned program and the required number of maneuvers in the orbits on approach of the spacecraft to its namesake satellite of Mars significantly depended on the accuracy of the Phobos ephemeris.[2] In order to improve the latter a qualitative jump was required in the accuracy of earth-based measurements realized in a sufficiently representative series of uniform observations. The unique astroclimatic conditions which characterized Maĭdanak mountain are the necessary preconditions for solving this specifically complex problem. By comparison with observatories situated in plains, the atmospheric turbulent smearing of an image is on the average by a factor of 2-3 lower on Maĭdanak mountain and, consequently, the random errors of coordinate measurements are correspondingly lower. Together with a decrease in turbulence the concentration of energy in images of starlike objects such as the satellites of Mars increases quadratically and this improves in proportion the threshold for locating an object on the background base. Under these favorable conditions the main problem in developing the methodology of observations consisted of discovery and suppression of sources of systematic errors the contribution of which was either not noted or ignored in previous earth-based observations.

From the point of view of celestial mechanics, the orbit of a satellite of a planet can be computed on the basis of any of the three types of coordinate measurements referred either to stars of a reference catalog, or to the visible center of the discs of the planets, or to another satellite of the planet if such exists. In the latter case, the orbits of both satellites are computed together. Since it was difficult to predict in advance which of the three choices of reference would provide the highest accuracy of the ephemeris, the program of observations was aimed at the possibility of obtaining all types of coordinates simultaneously.

Observations of the satellites of Mars were carried out by the methods of photographic astrometry using the first telescope of the Institute of Physics of the Academy of Sciences of the Lithuanian SSR at the 13.2m focus. Before the observations were started the telescope was carefully adjusted, and all the optical surfaces were washed in order to reduce light scattering. In order to equalize the surface brightness of Mars and its satellites a special mask was used which reduced the light from the disc of the planet by a factor of 600. The mask with a metallodielectric coating developed at the Astronomical Observatory of the Khar'kov State University specularly reflected not more than 1% of the light falling on it, and this significantly reduced the concentric specular bright spots on the preceding optical elements of the lightpath. It was decided to operate in the region V since in this spectral range the systematic errors associated with chromatic refraction are considerably lower. The motion of Mars among the stars in the course of the exposure was compensated by the Metcalf method modified by ourselves. The field of the "Zeiss-1000" telescope free from third order aberrations amounts to 40′, and as a rule stars of the reference catalog do not fall within it. The introduction of "secondary" reference stars was accomplished using the wide-angle (5°) astrograph AFR-1 ($D = 23$ cm, $D : F = 1 : 10$) which after many years of operation in Moscow was in the summer of 1988 operationally disassembled and transported to Maĭdanak mountain. As a result the "secondary" reference stars were obtained at the same place where Mars and its satellites were observed and practically at the same epoch.

Using the above methodology during the observational period from 23 July to 4 November in the course of 19 nights there were obtained 856 images of Phobos and 937 of Deimos. The two satellites were visible simultaneously on 810

 0038-5670/89/070639-02$01.80

negatives[3], from which 626 were selected for operational treatment. In December 1988, 1252 measurements for each satellite were transmitted to the flight control center. Analysis of the measurements made on the basis of satellite theory[1] developed to satisfy the requirements of the "Phobos" project showed that the greatest accuracy is obtained from differential measurements Phobos-Deimos in astrometric coordinates. The r.m.s. discrepancy of a single measurement with the ephemeris taken over the entire Maĭdanak material amounted to 0".120.

In the first set of measurements carried out by the spacecraft "Phobos-2" on 21 February 1989 the Phobos image turned out to be at the center of the narrow field of vision. During the second set of measurements on 28 February 1989, 15 images of the satellite were obtained. The r.m.s. discrepancy computed on the basis of these data amount to 2km. On recalculation to the average opposition this quantity amounts to 0".005. The difference by a factor of 24 between the accuracy of a single Maĭdanak measurement and the resulting accuracy indicated the absence of systematic errors of any significance. The achieved accuracy of earth-based positional observations has no analogs in world practice.

[1]N. M. Ivanov, Yu.F. Kolyuka, S. M. Kudryavtsev, and V. F. Tikhonov, Pis'ma Astron. Zh. **14**, 956 (1988) [Sov. Astron. Lett. **14**, 405 (1988)].
[2]V. A. Shor, *ibid.* **14**, 1123 (1988) **14**, 477 (1988).
[3]S. B. Novikov, *ibid.* **15**, 270 (1989) [**15**, to be published (1989)].

Translated by G. M. Volkoff