ISSN 1063-7842, Technical Physics, 2024, Vol. 69, No. 6, pp. 1518–1520. © Pleiades Publishing, Ltd., 2024.
Russian Text © The Author(s), 2023, published in Zhurnal Tekhnicheskoi Fiziki, 2023, Vol. 93, No. 12, pp. 1768–1770.
English Text © Ioffe Institute, 2023.

Creation of a Multiparameter Model of a Space Telescope Observation System

K. O. Churkin[a,*], N. K. Petrova[a,b], Yu. A. Nefedyev[a], A. O. Andreev[a,b], and N. Yu. Demina[a]

[a] *Kazan Federal University, Kazan, 420008 Russia*

[b] *Kazan State Power Engineering University, Kazan, 420066 Russia*

**e-mail: kchurkin87@gmail.com*

Received May 11, 2023; revised August 22, 2023; accepted October 30, 2023

Abstract—The possibility and effectiveness of using an automated zenith telescope to determine selenodetic rotation parameters by computer simulation of observations using a telescope installed on the lunar surface are considered, in particular, modeling of star tracks at an automated zenith telescope and the possibilities of astrophysical research, development of a space observations program.

Keywords: meteor shower, radiants, meteor complex, resonances

DOI: 10.1134/S1063784224060070

A series of space astrophysical experiments are planned for the next decade in many countries. One such project is the installation of an optical telescope on the lunar surface. A qualitatively new type of observations with the help of lunar measuring instruments allows us to hope for long-period astrophysical observations both within the Solar System and in deep space, as well as to significantly improve the ephemerical tracking of spacecrafts [1, 2]. In Russia, it is planned to install an automated zenith telescope (AZT) on the Moon. One of the best places to place it – is the polar zones of the Moon. This has a number of advantages compared to other points on the lunar surface. The possibilities of such an experiment for determining the parameters of the Moon's rotation were investigated by the method of computer simulation, which is the subject of this paper. The results and tools of our study will allow us to solve a number of problems in the practical use of the lunar telescope, namely:

(1) simulation of star tracks on AZT;

(2) determination of the possibility of astrophysical research;

(3) development of a space observation program.

The advantage of lunar observations is that they have a different sensitivity to libration amplitudes and frequencies than the lunar laser ranging (LLR), which, together with LLR, will significantly improve the quality of observations of lunar rotation [3].

In order to study the position of the lunar body in space at any point in time, the so-called dynamic coordinate system (DCS) – x, y, z is introduced in the construction of the theory of lunar physical libration (LPL), the axes of which are the principal axes of inertia of the Moon a, b, c, and the center of the DSC is located in the center of mass of the Moon (Fig. 1). For a solid Moon, the DSC is tightly bound to its body.

The simulation process of observations with the lunar polar telescope assumes that it is installed strictly at the point of the lunar pole, which is defined by the main axis of inertia of the Moon c. Its vertical axis is an extension of that axis. The other two axes – a and b – define the coordinate system in the plane of the telescope objective.

Computer simulation of observations of stars with the help of a lunar telescope required, first of all, the creation of a list of stars falling into its field of view for a given period of observation. The field of view of the telescope was given by a plate with a side of 1°. Stars brighter than 12th magnitude were selected from star catalogs. The developed programs made it possible both to select stars with the appropriate coordinates and magnitudes, and to convert equatorial coordinates into ecliptic coordinates, considering the corrections for precession, aberration, and the proper motion of the stars. The result, for the north and south poles, the list included more than 800 stars in the ring 1° relative to the precessional track of the poles. Figure 2 shows the stars in the vicinity of the Moon's north pole. The pole and the selected stars are located in the Draco constellation.

A successful tool for calculating the "of the observed" coordinates of the stars was the analytical theory of LPL by N. K. Petrova [4]. Based on it, it is convenient to calculate the position of stars not only for any given time interval, but also for any model of the gravitational field. Inasmuch as the pole stars

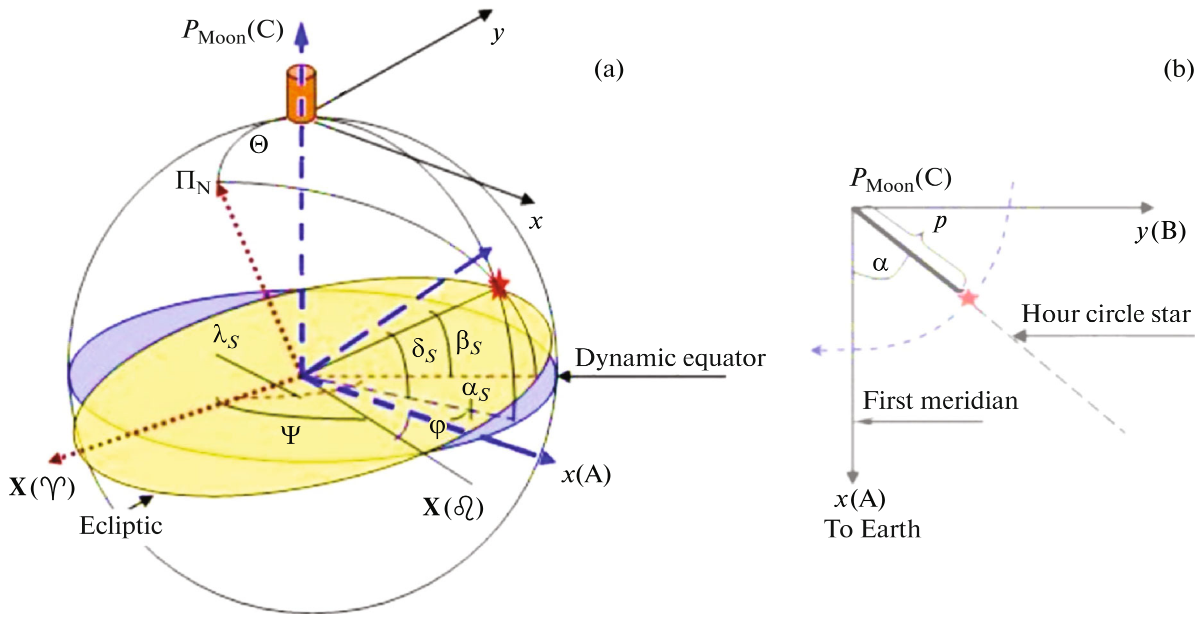

Fig. 1. (a) Position of the DSC relative to the inertial ecliptic coordinate system ($\overline{X}\overline{Y}\overline{Z}$). It is given by classical Euler angles – Ψ, Θ, φ. (b) The position of a star in the field of view of a polar telescope is described by either the polar distance p and the hour angle α or the rectangular coordinates x, y. The Moon's rotation parameters – angles $\tau(t)$, $\rho(t)$, $\sigma(t)$ – are a kind of reduction functions to bring the uniform rotation of the Moon to its actual motion.

move slowly, the calculation could be performed at intervals of 3–5 days without losing significant effects in the libration rotation of the Moon. Figure 2 shows the precessional motion of the North Pole from January 2013 to January 2014. In this period, 48 stars came into the telescope's field of view.

As a result, we were able to obtain tracks of these stars and analyze their behavior. In contrast to observations from the Earth, the stars as seen from the

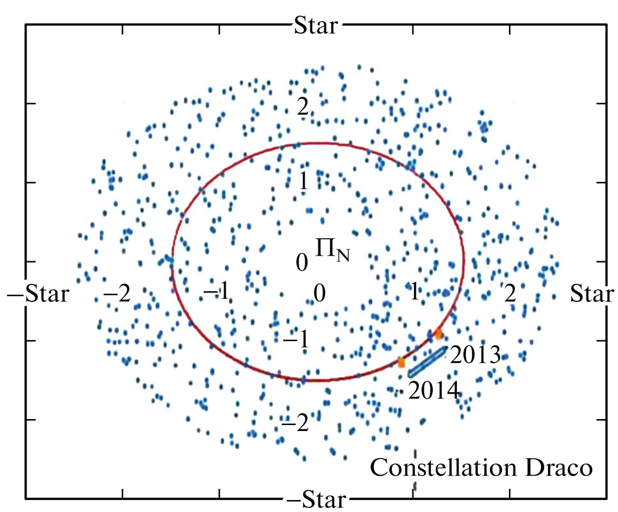

Fig. 2. Dots indicate stars that are located in the vicinity of the precessional motion of the lunar pole relative to the pole of the ecliptic in the ecliptic coordinate system Π_N. Its movement from 2013 to 2014 is shown by an arrow.

Moon move in spirals, and some of the stars show loop-like tracks (Fig. 3), this is due to the slow rotation of the Moon and the relatively fast precessional motion of the lunar pole.

An equally important study was the study of the sensitivity of the measured coordinates of the stars to the parameters of the dynamical model of the Moon, namely to the values of its moments of inertia and Stokes coefficients, the numerical values of which were obtained from various gravimetric measurements. We have studied dynamic models based on data from the Clementine, Lunar Prospector and SELENE (Kaguya) satellites. It turned out that the accuracy of the measured coordinates of the star x, y significantly depends on the selected model of the Moon's gravitational field [4].

In addition to astrometric tasks, the telescope on the lunar surface will allow for more accurate and reliable astrophysical observations due to the absence of an atmosphere. To exclude the influence of sunlight, the telescope can be placed in polar lunar craters: the specifics of the Moon's rotation are such that the Sun never rises higher than one and a half degrees above the horizon at the north and south poles of the Moon, and as a result, in the areas near the poles, light never penetrates the bottom of some craters.

Great prospects are also opening up for the study of exoplanets with biosignatures. When observed from the Earth, spectral analysis of the atmospheres of exoplanets is difficult, and a lunar telescope will solve this

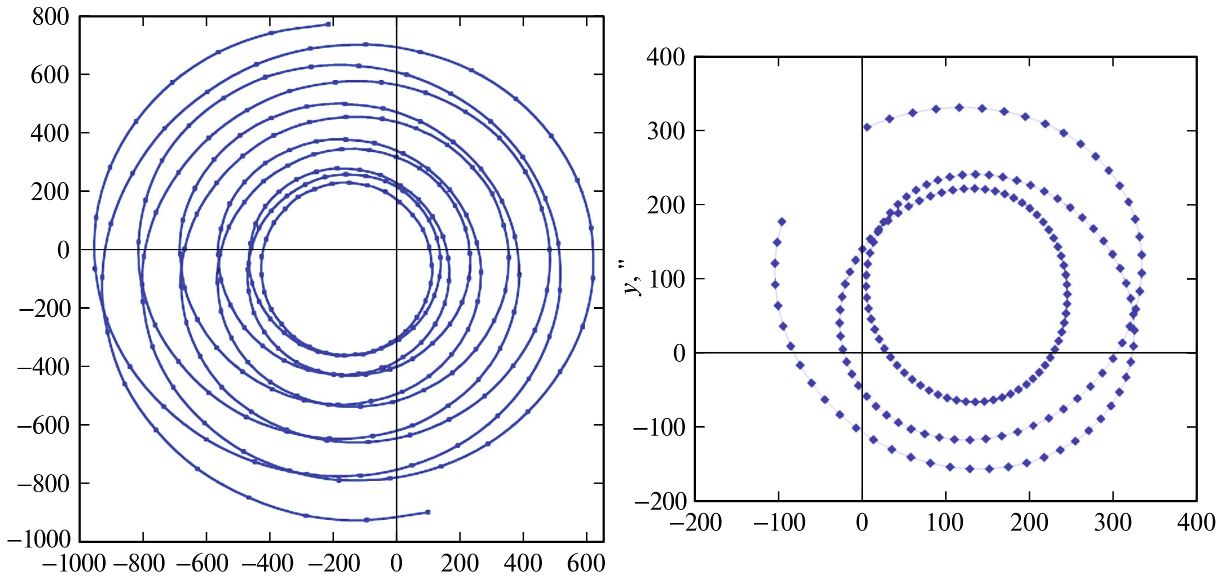

Fig. 3. Tracks of stars from lunar telescope simulations.

problem. It will also be possible to study supermassive black holes at a higher level [5].

FUNDING

The authors express their gratitude to the Russian Science Foundation for the support of the work performed, grant No. 22-72-10059.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. M. Imai, J. Kurihara, T. Kouyama, T. Kuwahara, S. Fujita, Y. Sakamoto, Y. Sato, S.-I. Saitoh, T. Hirata, H. Yamamoto, Y. Takahashi. Sensors, **21**(7), 2429 (2021). https://doi.org/10.3390/s21072429
2. T. Wilson, X. Xiong. J. Appl. Remote Sens., **13**(2), 024513 (2019). https://doi.org/10.1117/1.JRS.13.024513
3. N. K. Petrova, Y. A. Nefedyev, A. O. Andreev, A. A. Zagidullin. Astron. Rep., **64**, 1078 (2020). https://doi.org/10.1134/S1063772920120094
4. A. A. Zagidullin, V. S. Usanin, N. K. Petrova, Y. A. Nefedyev, A. O. Andreev, T. V. Gudkova. Astron. Rep., **64**(12), 1093 (2020). https://doi.org/10.1134/S1063772921010066
5. L. S. Pilyugin, B. Cedres, I. A. Zinchenko, A. M. Perez Garcia, M. A. Lara-Lopez, J. Nadolny, Y. A. Nefedyev, M. Gonzalez-Otero, J. M. Vilchez, S. Duarte Puertas, R. Navarro Martinez. Astron. Astrophys., **653**, A11 (2021). https://doi.org/10.1051/0004-6361/202141012