NATIONAL HELIOGEOPHYSICAL COMPLEX OF RAS: LARGE SOLAR TELESCOPE OPPORTUNITIES FOR SOLVING FUNDAMENTAL PROBLEMS OF SOLAR PHYSICS

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The “National Heliogeophysical Complex of the Russian Academy of Sciences” is designed to develop methods to forecast space weather phenomena, the vast majority of which are related to solar activity. Developing methods for predicting solar activity requires solving fundamental problems in solar physics. These tasks set a high bar for achieving the required experimental parameters, such as angular, spectral, and temporal resolution. The Large Solar Telescope LST-3 will conduct relevant observations of the Sun’s atmosphere for the next 50 years. This will provide the essential data needed to develop physically-based models, which are crucial for understanding the causes of various energetic phenomena, including geoeffective events.

The research directions are to understand the development of active regions and to investigate the origin, structure, and evolution of magnetic fluxes; to obtain new observational data on solar flares and eruptive events for identification of triggering mechanisms that disrupt the equilibrium; to determine the connection between the layers of the solar atmosphere through waves and magnetic fields; to study the dynamics of the chromosphere, as well as magnetism and heating of the upper atmosphere.

The task is to observe physical processes at the scales at which they occur: approximately 70 to 150 km, which corresponds to the mean free path of a photon and the pressure scale height in the solar atmosphere. It is crucial to enable simultaneous observations of the photosphere, temperature minimum, and two levels in the chromosphere. The range of heights is about 3000 km. Practically, this leads to the requirement of simultaneous registration of 10–20 spectral lines from different spectrum ranges: visible (380–800 nm) and near-infrared (800–2500 nm). Temporal scales of observed phenomena impose very high resolution requirements: from 1 to 100 seconds, with observation durations up to 8 hours or longer. In angular measure, the observed objects (sunspots, filaments, faculae, granulation structures, and other magnetic structures) occupy 50–120 arcseconds on the solar disk. It is crucial to ensure spectropolarimetric observations and precision measurements of the magnetic field vector ranging from 5 to 70 Gauss for scales of 1 to 0.1 arcseconds. Studying plasma flows and periodic material movements necessitates achieving the accuracy of Doppler velocity measurement up to 5 m/s, with supersonic speeds ranging from 5 to 20 km/s depending on different physical conditions.

Fundamental solutions to these problems are feasible with a telescope aperture diameter of 3 to 4 meters with certain compromises. It is impossible to cover a wide range of parameters with a single instrument for spectral analysis. The solution lies in optimal distribution of various observational tasks among several scientific instruments to ultimately reconstruct the three-dimensional structure of the solar atmosphere. Primarily, the needed parameter range can be covered using filter instruments and spectrographs. The project includes two main instruments: a narrowband filtergraph and a spectrograph with an integral field unit. The former allows capturing images of the fine structure of the solar atmosphere, while the latter offers high accuracy in Doppler velocity and magnetic field measurements for a limited spatial area. Additionally, two other instruments, a broadband filtergraph and a slit spectrograph, enable the registration of rapid processes in the image plane and any spectral lines from the visible and near-infrared spectrum. The estimated data output flow from scientific instruments is expected to be 5 GB/s, with a potential up to 56 GB/s.

To enable the simultaneous operation of multiple focal instruments, it is necessary that the light flux on each of them is sufficient to achieve an acceptable signal-to-noise ratio. This can be achieved through high efficiency of the main optical system of the telescope, which should provide a relatively high transmission coefficient, as well as a relatively high image contrast. The optical system is designed to achieve diffraction-limited quality. Improving image quality under Earth's atmospheric conditions is accomplished through adaptive optics, as well as by creating local conditions using the dome, thermal stabilization systems, and climate control.

The LST-3 project fully meets the requirements of the current solar physics missions and will ensure:

– Multispectral measurements of the magnetic field vector and plasma motions;

– High spectral resolution;

– High spatial resolution over a large two-dimensional field.