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Development of Solar Observations in Bulgaria: New 30-cm Chromospheric Telescope

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Abstract. The development of solar observations during the last decades and the growing influence of space-based telescopes turns the ground-based monitoring of the Sun into complementary activity. Nevertheless, new solar telescopes continue to be established as they excel space-borne instruments with the immediate access to the received data and relatively low completion cost. In 2019 a project for establishing a new 30-cm solar telescope in the National Astronomical Observatory Rozhen (Bulgaria) was launched. This paper summarizes the primary goals and objectives of the telescope as well as its stage of construction.

KEY WORDS: Chromosphere, Solar observations, Telescope.

1 Introduction

In 1946, soon after the World War II ended, the launch of V-2 rocket for solar physics and atmospheric research marked the beginning of the space science era [1]. The data from space-based instruments collected since then presents huge amount of information with unprecedented quality. Such observations offer high spatial and temporal resolution and allow studying of small-scale structures and dynamics – a complicated task for ground-based telescopes because of the turbulence of the Earth's atmosphere.

Today, hundreds of ground-based and dozens space-borne telescopes are useful tool for solar research. Space-based instruments, of course, get a much clearer view of the universe than most of their ground-based counterparts. They are capable of detecting frequencies and wavelengths across the entire electromagnetic spectrum. This is especially valuable for the parts of the spectrum that are being absorbed by the Earth's atmosphere. The ultraviolet spectroscopy and in-situ particle measurements revealed fundamental knowledge of the outer solar atmosphere and solar-terrestrial interaction. Still, space-based telescopes remain expensive to build and difficult to maintain.

As technology advances, both telescopes on the ground and in space are continuing to improve. Compared to their space-based twins, ground-based telescopes can be constructed bigger and cheaper, easier to sustain and upgrade. Their commissioning is not connected with the risk of being damaged by the unpredictably moving space junk. They are often located in isolated, elevated locations to escape the troubles with light pollution, but still cannot completely escape the atmospheric distortion. Anyway, the progress of ground-based facilities during the last decades including these in telescope constructions and data processing techniques makes them scientifically very valuable.

To obtain a detailed idea about processes taking place at our Sun we must study their nature by tracing what is happening not only at the surface, but also in-depth. While most of the absorption lines form in the upper photosphere, few others (like H_α, H_β, CaII H and K, etc.) are produced and can give us a sight on the chromosphere. Using variety of filters for solar observations allows investigating different layers of solar atmosphere. The new 30-cm telescope in Bulgaria will be equipped with H_α filter. It will let us observe the light emitted by hydrogen atoms (the most common element in the Sun) when electrons within these atoms cascade back to their original orbits as before they raised to a higher energy level (because of absorbing energy). The wavelength of the released light is 6562.8 Å.

2 Solar Observations in Bulgaria

In 1899, five years after establishing the first Bulgarian astronomical observatory in Sofia, Marin Bachevarov started regular sunspot observations with his students with the foremost contemporary telescope in Bulgaria - a 6-inch refractor [2].

In the mid-XXth century Angel Bonov lays the foundation of solar physics in Bulgaria with his studies on the 22- [3], 44- [4] and 176-year [5] cycles of solar activity and the first heliophysics course, led in Sofia University. Other scientist, like Marin Kalinkov and Donka Raikova, also give their contribution in solar research in the newly established Astronomical Department in the Institute of Physics of Bulgarian Academy of Sciences in 1952.

In 1977 Vladimir Dermendzhiev becomes the first to get a PhD in heliophysics in Bulgaria after defending a thesis “Study on the height, heliographic distribution and activity cycles of solar prominences”. In 1985 he established Solar Physics Department and marks the beginning of regular and extensive research on Sun and solar activity in our country.

In the early 1990s, a solar tower with 8-m Carl Zeiss dome, built in the National Astronomical Observatory (NAO) Rozhen, marks the first steps of observational heliophysics in Bulgaria. It was equipped with 13-cm refractor to explore solar photosphere (Figure 1, left panel). The initiator and head of the project was

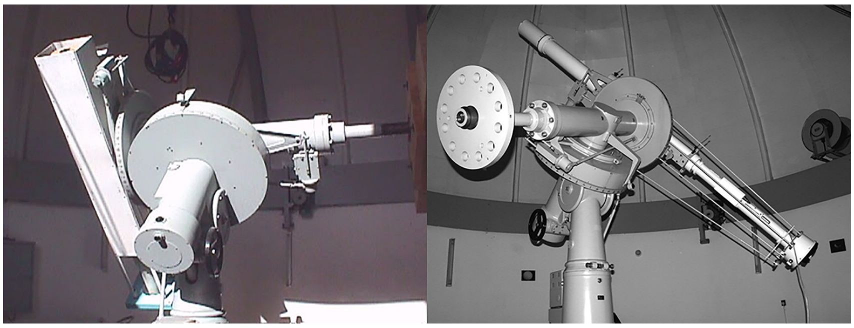

Figure 1. The first two telescopes located at the solar tower in the Bulgarian National Observatory: 13-cm refractor from the beginning of the 1990s (left) and 15-cm coronagraph from 2005 (right).

Vladimir Dermendzhiev. After almost 15 years of usage, in 2005 the 13-cm telescope in the solar tower of NAO is replaced by 15-cm coronagraph (Figure 1, right panel). Supplied with H_α filter, its main purpose is dedicated to observations of solar prominences.

Meanwhile, for less than 40 years the path of lunar shadow passes through Bulgarian lands twice - in 1961 and in 1999, and solar physicist use the opportunity to organize total solar eclipse observations. On 15 February 1961 despite the unfavorable weather conditions Marin Kalinkov makes one of the first successful attempts in Europe to observe the eclipse aboard plane in order to extend the totality (Figure 2, left panel) [6]. The expedition, held 38 years later (on 11 August 1999) in northwestern part of the country included more participants and

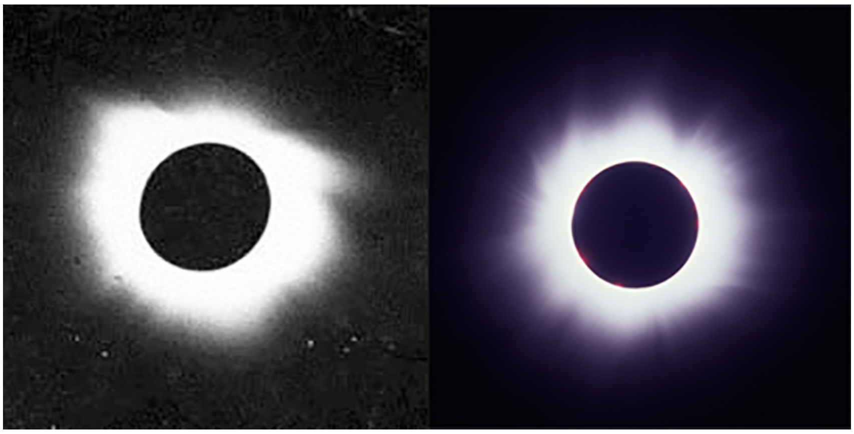

Figure 2. The solar corona during the total solar eclipses on 15 February 1961 (left) and on 11 August 1999 (right), photographed by M. Kalinkov and N. Petrov, respectively.

scientific experiments under the supervision of National Council for Coordination of Observational Programmes (headed by D. Mishev) [7]. The observations were successful covering topics from spectral and white-light observations of the corona (Figure 2, right panel) to geomagnetic and seismological research. This two events establish the Bulgarian total solar eclipse observations. In the years after it outgrows in organization of Bulgarian solar eclipse observational expeditions abroad with the eclipses in 2006 [8], 2009 [9], 2017 [10] and 2019 [11].

In 2019 a project for construction of new solar telescope in NAO Rozhen started. It is currently in its final phase and the telescope is expected to receive its first light in 2021.

3 The Telescope

3.1 Location

The infrastructure and the developed working conditions of NAO Rozhen predetermined the new solar telescope to be located in the solar tower (41°41'51" N 24°44'19" E). Situated in Smolyan province at altitude 1759 m it offers good opportunities for regular observations as weather conditions in the observatory are assumed as appropriate for solar monitoring. The building is electrified and provided with fast and secure fiber-optic internet connection. The current pillar support and recently renewed mount will be used when installing the new telescope, whereupon the computer systems that service the telescope will be completely replaced according to the technical requirements of the used new software.

3.2 Characteristics

The new instrument is designed as Schmidt–Cassegrain telescope with 305 mm aperture and 3050 mm focal length. Tracking of the Sun will be assured by Hinode solar guider. The front part of the tube will be supplied with K8 flat glass filter with bandwidth 6560±500 Å. It reflects more than 94% of the electromagnetic emission in the non-working regions of the spectrum to protect the interior of the tube from superheating. Then the optical path passes through a Schmidt plate before the light reaches the 305-mm primary (concave) mirror that will gather light back to the focal point where the secondary mirror is positioned. It is convex mirror and redirects the light beam to the focal point behind the primary mirror. But before reaching it, the light will successively pass through a system of telecentric lens (that extends the focal length) and 0.75×–0.4× focal reducer, and H_α filter. The bandwidth of the filter will be about 0.3 Å and will allow maximal shift ±0.5 Å by step 0.1 Å. The narrower the filter wavelength, the more off-band light is eliminated and the contrast is greater. The system for focal length correction determines an effective focal length between

5000 and 15000 mm and, respectively, a field of view varying from $2.5' \times 2.5'$ to $10' \times 10'$. Thus, the telescope will be different from the most common H_α instruments used nowadays by providing a detailed view of selected areas of the Sun instead of full-disk observations. These and other parameters of the telescope are listed in Table 1.

Table 1. Main parameters of the telescope

Parameter	**Value**
Aperture D	305 mm
Focal length F	3050 mm
Effective focal length F_{eff}	5000-15000 mm
Field of view	$2.5' \times 2.5' - 10' \times 10'$
Spectral range	656.28 nm (H_α)
Spatial resolution	$0.5''$
Line-of-sight velocity resolution	0-10 km/s

3.3 Aims and goals

Since the telescope is designed for H_α observations, its main object of study will be solar chromosphere and activity phenomena occurring there. Regular observations of the chromosphere reveal the evolution of prominences/filaments and their supporting magnetic field configuration. The high spatial resolution allows not only achieving a detailed picture of brightened regions of flares as well as the associated active regions, but also registration and analyses of small-scale events in solar atmosphere. The study of energy release and mass ejection of minor eruptions is a recently popular topic in heliophysics, because of the hypotheses for their contribution to coronal heating and solar wind acceleration. Systematic observational data for these events may help classifying all the flares and filament eruptions in subtypes by monitoring their development from the flux emergence to disappearance.

Another aspect of solar physics nowadays is dedicated to the connection between different active processes. A combination of H_α data with information obtained by other ground-based or space-borne instruments is important to better understand the driving mechanisms of different phenomena and the relations between them. Every source of a high quality solar observations is important for improving our skills in solar activity forecasting.

The plans for future development of the telescope include equipping with motorized fast-change filter wheel that will offer observations in two additional wavelengths – 4305 Å (G-band filter) and 3933 Å (CaII K filter). It will expand the possibilities for studying layers of solar atmosphere with lower temperature (4000–6000 K) than the observed by H_α (40000 K).

4 Conclusions

The start of the project for construction of a new solar telescope in Bulgaria was given in 2019. It was planned to receive its first light from NAO Rozhen in the summer of 2020, but some delays postponed the opening for 2021. The 30-cm chromosperic telescope will be the third instrument placed in the solar tower of Bulgarian National Observatory after the 13-cm refractor from the beginning of the 1990s and the 15-cm solar coronagraph from 2005. Its main scientific purpose will be to offer regular H_α observations of the solar chromopshere and to study the evolution of large- and small-scale active structures like active regions, prominences/filaments, flares, fibrils, spicules, etc.

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