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OPTICAL OBSERVATIONS OF SOLAR CHROMOSPHERE IN NATIONAL ASTRONOMICAL OBSERVATORY

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Abstract. There is hardly a person nowadays who has not heard and is not concerned about the growing climate problems threatening the life of most plant and animal species on Earth, including the humankind. We understand more and more that one of the important factors determining the global trends of climate changes on Earth is the cosmic influence on the magnetosphere, atmosphere and biosphere of our planet. But of all the cosmic factors, the Sun and solar activity are undoubtedly the most important one and play a crucial role for all processes on Earth. This is the main reason for the widespread scientific interest in studying and understanding the physics of the Sun. New both ground- and space-based observing programs that aim to observe and study solar activity are being introduced every year. Exploration of solar chromosphere, where many active processes take place and new ones often emerge, is among the important problems that ground-based telescopes are capable of solving. It is also one of the main tasks of the of Sun and Space Weather Department at the Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences. The long-term efforts of our entire team led to the financing, construction and establishment of the first chromospheric telescope in the National Astronomical Observatory Rozhen. We present the main parameters and possibilities of our new 30-cm chromospheric telescope.

1. INTRODUCTION

Solar chromosphere ("color sphere") is situated directly above the visible surface of the Sun, called the photosphere ("light sphere"), which provides the light which is dominant for human vision. Except for the moments right before and after the totality during solar eclipses when the chromosphere could be seen as a thin purple-red ring surrounding the Moon's dark disk (Figure 1), it remains invisible to the human eye. Since it is located immediately above the point of temperature minimum in the solar atmosphere, the density in its lower part decreases rapidly with height. Therefore, the general reduction in density (10^{-4} times) is also large, which explains many of the characteristics of the chromosphere.

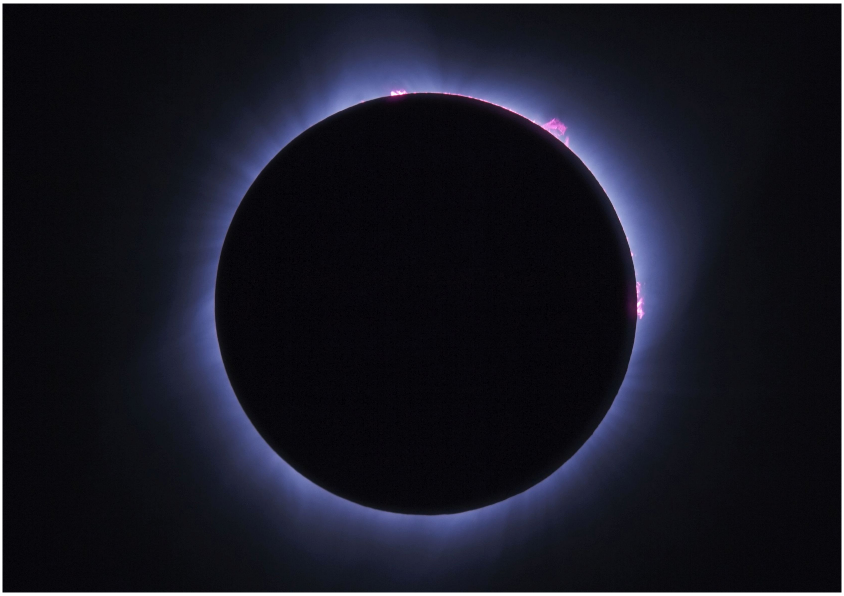

Figure 1: The solar corona and the chromosphere as photographed during the third contact of the total solar eclipse in 2017 (USA).

Studying the chromosphere, we are capable of finding answers to the questions connected to wave propagations (Mullan D. J., 2010). When high-frequency sound waves originating in the turbulent convective zone penetrate the chromosphere, they undergo two changes that are responsible for the heating of the chromosphere from 4300 K to almost coronal values:

- Due to the rapid drop in density, they accelerate and become shock waves. More energetic particle impacts lead to stronger heating as the wave passes.
- The reduced density of matter and the presence of magnetic field increases energy transfer by MHD waves. They propagate along the magnetic field, induce oscillations of the charged particles, which leads to more collisions between them and with neutral particles and finally the energy of the wave is converted into heat.

On the other hand, there are numerous active manifestations of solar activity that determine space weather and thus influencing the Earth's climate (Nikolov & Petrov, 2014; Pomoell & Poedts, 2018) – flares, coronal mass ejections, bulges/filaments, solar energetic particle events (Wang et al., 2003; Jiang et al., 2014, Tsvetkov et al., 2019).

2. 30-CM CHROMOSPHERIC TELESCOPE

A brand new Schmidt-Cassegrain telescope with 305 mm aperture and 3050 mm focal length was installed in the solar tower of National Astronomical Observatory (NAO) in 2022 (Figure 2).

Figure 2: 30-cm chromospheric telescope, installed in the solar tower in National Astronomical Observatory.

It is equipped with K8 flat glass infrared (IR) filter with bandwidth 6560±500 that reflects more than 94% of the electromagnetic emission in the non-working regions of the spectrum to prevent superheating of the telescope (Figure 3). To reach the desired and necessary selectivity (passband), thin layers of various metals and their oxides are applied successively on a glass pad. The IR filter is covered on both sides with a layer of quartz, which is also a protection against atmospheric microparticles or dust. Unfortunately, sensitivity to moisture is a common property of many metals and their compounds, but filters larger than 30 cm in diameter that are insensitive to moisture are still difficult to produce, which raises their price repeatedly.

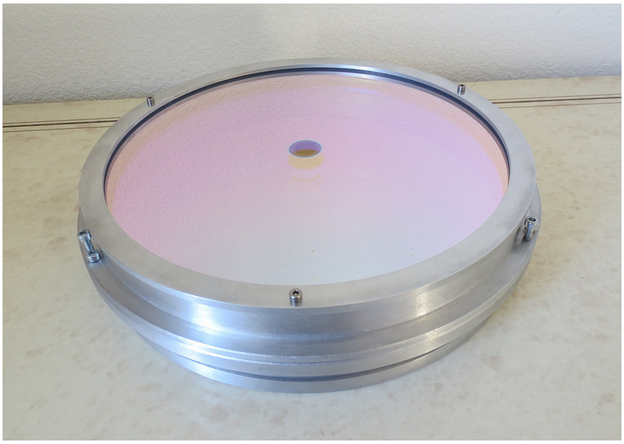

Figure 3: The infrared filter of the 30-cm chromospheric telescope.

Before reaching the focal point behind the primary mirror, the light also passes through a system of telecentric lens extending the focal length, 0.75 – 0.4× focal reducer, and Hα filter with bandwidth of about 0.3 Å. The focal length correction system determines an effective focal length of the telescope varying between 5000 and 15000 mm and an observational field of view below 10×10 arc min. This differentiates our telescope from the most common Hα instruments used nowadays as it provides a detailed view of selected areas of the Sun instead of full-disk observations.

3. OBSERVATIONAL CONSIDERATIONS AND POSSIBILITIES

As with any optical system, with the 30-cm telescope in NAO it is better to observe the central parts of the solar disk, rather than near the solar limb since the contrast of surface detail is much higher in the central regions. The intensity of the various manifestations of solar activity near the limb often shows higher amplitude, which necessitates at least 16-bits receivers. Of course, in order to avoid non-uniform illumination (vignetting or "light fall-off"), it is mandatory to make flat fields during every observation. Also, it would help to clear the images from the dust particles on the surfaces of the various optical elements or non-uniformity of transmission of the narrow-band Hα filter.

Receiving the raw images, it is better to have a lower illumination of the frame than a maximum filling of the digital matrix. The shorter the exposure, the more likely it is to get clear/contrasted photos. With shorter exposures (but more than a second), the perfect images can be obtained at the best seeing by removing the effect of atmospheric scintillations. The raw image capture technique we use involves video recording for 5-10 seconds. This allows taking 500-1000 single frames followed by a procedure of stacking the best quality images, where we can reach the maximum of the signal-to-noise ratio, as well as the best resolution of our optical setup – about 0.3".

Observing the Sun near the limb in Hα line (6563 Å), we see that the chromosphere is not a homogeneous region, but it consists of many separate bright line structures (Figure 4). They rise in height from the photosphere up to several thousand kilometers. They are called spicules and appear as spike-like formations in Hα. When detected on the solar limb, the spicules appear bright due to the lack of background light to be absorbed (the spicules are like emitting structures), while on the solar disk they are dark because of the absorbed the light of H-alpha photons.

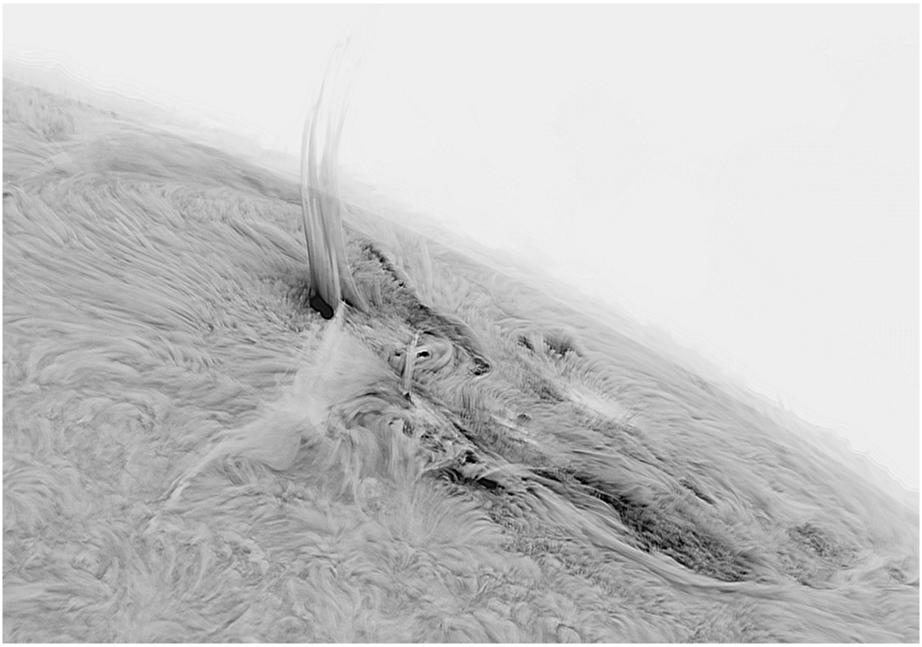

Figure 4: Image of an active region and chromospheric environment near the solar limb, obtained with the 30-cm telescope.

Another typical for the chromosphere formation could be noticed in Hα observations – chromospheric network. Their lifetime, appearance and transformation are still a matter of debate, which necessitates the constant monitoring of the active chromosphere on a large scale (full-disk solar observations). But it is also crucial to be able to obtain high-resolution observations so that the dynamics of the fine chromospheric structure can be determined more precisely. Of course, high-resolution observations are determined not only by the capabilities of optical instruments, but here the main role is played by the state of the atmosphere around the observers. Our observatory is located at altitude of 1740 m and offers good opportunities for regular observations as weather conditions in the observatory are assumed as appropriate for solar monitoring. These properties define our aim to determine the dynamics of the chromospheric fine structure with our new instrument. It may be the key to solving the physics of the interaction between the local magnetic fields of an active region and the solar plasma. Such interactions lead to the strongest manifestations of solar activity, such as prominence eruptions and CMEs.

4. CONCLUSIONS

Scientific solar observations passed through different stages over the years – visual observations, photographic methods, spectral detectors, coronagraphs, etc. The development of research techniques led to the beginning of observations from space in the last few decades, which have a number of advantages such as regularity, continuity, high temporal and spatial resolution. But still humankind continues to explore the Sun establishing new ground-based solar telescopes. The improvement of technologies for solar observations, the possibilities for constant and detailed monitoring of its activity allow us to further develop our ideas about the various active processes in solar atmosphere and the connections between them.

The recently installed 30-cm chromosperic telescope is the third instrument placed in the solar tower of Bulgarian National Astronomical Observatory after the 13-cm refractor from the beginning of the 1990s and the 15-cm solar coronagraph from 2005. Its scientific goals and objectives include offering regular Hα observations of the solar chromopshere as well as studying the evolution of large- and small-scale active structures like active regions, prominences/filaments, flares, spicules, etc.

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