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NEW BULGARIAN-AUSTRIAN PROJECT 'JOINT OBSERVATIONS AND INVESTIGATIONS OF SOLAR CHROMOSPHERIC AND CORONAL ACTIVITY'

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Abstract: *We present the bilateral collaboration between Bulgarian and Austrian solar and space weather researchers on the topic of chromospheric and coronal activity. This new project will focus, on one hand, on the technical setup and calibration of the new Rozhen chromospheric telescope at the National Astronomical Observatory (NAO): establishing optimal observational programs for different quiet-Sun and activity phenomena, automating the data collection and storage, implementing machine/deep learning models for feature recognition. The second aim is to carry out joint scientific analyses of solar phenomena using observations from ground-based instruments in both countries, and supplementary spacecraft data. The successful establishment of solar monitoring at NAO-Rozhen will facilitate the overall visibility of the Bulgarian instrument and generate interest towards solar physics and astronomy not only for PhD students and young scientists but also for the general public.*

НОВ БЪЛГАРО-АВСТРИЙСКИ ПРОЕКТ "СЪВМЕСТНИ НАБЛЮДЕНИЯ И ИЗСЛЕДВАНИЯ НА СЛЪНЧЕВАТА ХРОМОСФЕРА И КОРОНАЛНА АКТИВНОСТ"

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Ключови думи: *Слънчева физика, космическо време*

Резюме: *Представяме двустранното сътрудничество върху хромосферна и коронална активност между български и австрийски изследователи в областта на слънчевата физика и космическото време. Този нов проект ще се фокусира от една страна върху техническото оборудване и калибровка на новия хромосферен телескоп в Националната астрономическа обсерватория (НАО) - Рожен, а именно: установяване на оптимални наблюдателни програми за различни събития на спокойното и активното Слънце, автоматизиране на събирането и съхранението на наблюдателните данни, прилагане на модели за машинно обучение за разпознаването на различни характеристики. Втората цел е да се извърши съвместен научен анализ на слънчеви събития чрез наблюдения от наземни инструменти в двете страни, допълнено със спътникови данни. Успешното изграждане на програма за слънчеви наблюдения в НАО-Рожен ще подпомогне цялостната видимост на българския уред и ще стимулира интерес към слънчевата физика и астрономия не само при докторанти и млади учени, но и при широката публика.*

Introduction

We present a bilateral project on the topic of solar and space weather research, supported by the Bulgarian National Science Foundation (https://bnsf.bg/) and Austria's Agency for Education and Internationalisation (OeAD) as part of the Austria-Bulgaria scientific and technological cooperation under a competition procedure that took place in 2022. Science teams from the Institute of Astronomy with NAO - BAS (IANAO) in Bulgaria and the Institute of Physics with Kanzelhöhe observatory for solar and environmental research (KSO), University of Graz in Austria will take part in the project which focuses on ground-based observations of the low corona (chromosphere) complemented with coronal data provided by satellites.

A variety of instruments are used to monitor the Sun, both ground-based (white light, H-alpha (Hα, 6563 Å) and radio) and satellite ((extreme) ultraviolet (E)UV), soft (SXRs) and hard X-rays (HXRs), and gamma-rays). Multiwavelength observations have proven to be the norm for operational and scientific investigation of solar activity. The tasks planned under this joint collaboration include research of quiet (sunspots, quescent filaments, spicules) and eruptive processes on the Sun: solar flares, eruptive filaments, coronal mass ejections (CMEs), in situ solar energetic particles (SEPs), based on their chromospheric and coronal signatures. Ground-based imaging of the Sun is complementary to space-bourne observing and monitoring of solar activity. Its main advantages in the era of space-borne instruments are the relatively low cost of implementation and the ability to access the received data immediately. Furthermore chromospheric observations are normally not part of space based missions, as they focus mainly on wavelengths that are not observable from ground.

Aims

The goals of the proposed project are two-fold:

1. To set up the Rozhen Chromospheric Telescope (RCT), Petrov (2021), and develop standardized solar observing methodology and products, complementary to the Kanzelhohe Patrol Instrument (KPI) by means of strong technical cooperation between the team members. The experience of the Austrian team in solar monitoring and analysis will be invaluable for the timely and successful initiation of the solar observations in Bulgaria (NAO-Rozhen, Fig. 1 left), Pötzi et. al. (2020). Training and know-how exchange will be carried out during the entire duration of the project. The new observational data products in NAO-Rozhen will be organized in a complementary way to those in KSO (Fig. 1, right), which will complement and facilitate the combined use of the data products from both observatories. Testing and joint observational campaigns are also planned during the project, in order to provide a proof-of-concept for the selected monitoring programs or optimize them if needed.
2. To carry out combined solar observations with the two instrument suites and external (freely available space-based) resources, in order to study chromospheric signatures of quiet sun and pre-eruptive active regions and multi-wavelength manifestation of solar eruptive phenomena, their morphology and kinematics. These will include studies of the chromospheric magnetic network, solar spicules, the pre-eruptive configurations and dynamics of active region magnetic fields.

To achieve the scientific goal of the proposed project, we will use remote solar observations with high spatial and temporal resolution to characterize the early stages of coronal eruption events in a systematic way by studying the pre-eruptive behavior of filaments and flares during energy build-up, the kinematics and morphology of CMEs and compressive shock waves, and the signatures of high energy non-thermal particles in both remote and in situ observations.

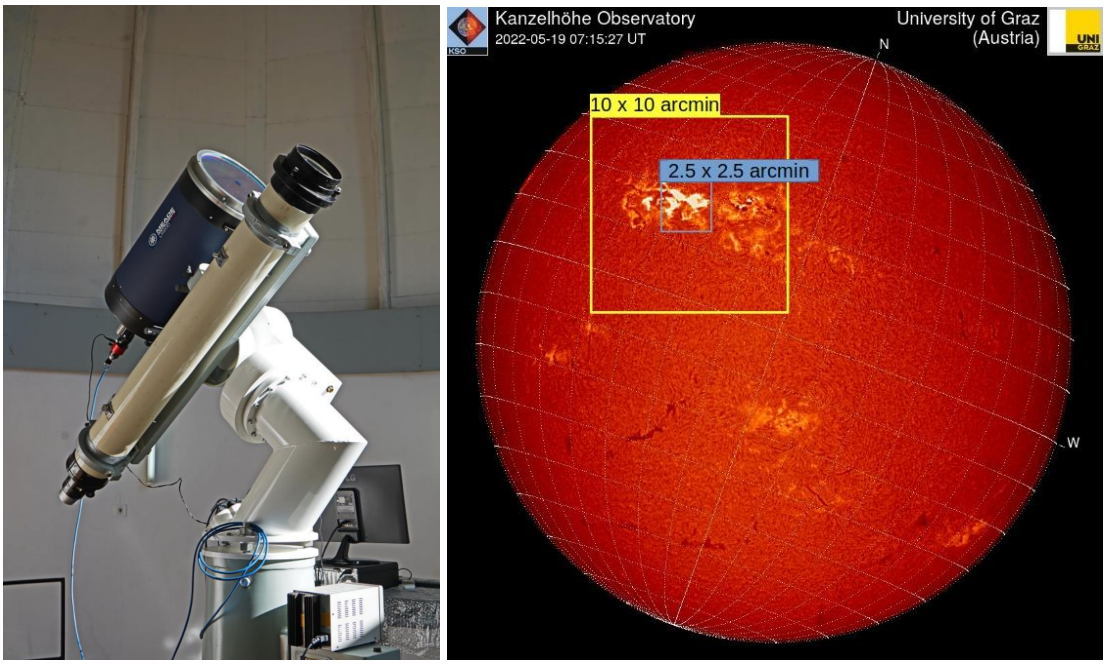

Fig. 1. Left: The 30-cm chromospheric telescope, installed in the solar tower in the National Astronomical Observatory-Rozhen, Bulgaria. Right: A solar observation snapshot made with the Kanzelhöhe Patrol Instrument's Hα telescope showing the full solar disk together with the two fields of view provided by the new Rozhen Chromospheric Telescope, both overlaid on an active region.

Project structure and timeline

The project is organized under 3 work packages (WPs) consisting of different tasks (Ts):

WP1: Technical support of NAO-Rozhen Chromosphere Telescope and observation campaigns with KSO facilities

- Task 1.1: Telescope installation

This task comprises the technical and mechanical part of the project. In order to obtain observations of sufficient quality the new 30cm reflector telescope has to be installed and tested.

- Task 1.2: Data processing

This task contains the software part of the telescope operation and the data processing. The main goal is the development and documentation of observation modes, data and metadata formats and products, their subsequent (automated) inspection, qualification and storage for the case of NAO-Rozhen solar observations. Databases or catalogs are planned to be developed.

- Task 1.3: Observation Campaign

This task outlines the observational part of both observatories NAO Rozhen and KSO. In order to profit from both, the full disk observations at KSO and the high resolution observations at NAO-Rozhen, campaign observations are planned.

- Task 1.4: Image enhancement

During this Task we will develop and apply deep learning algorithms that make use of the short-exposure high frame rate observations (>4/sec) that both KSO and RCT telescope systems can achieve, in order to reconstruct enhanced images from the multi-frame data, with a cadence of a few seconds. The method will be based on the Image-to-Image translation algorithm recently developed by the Graz group (Jarolim et al. 2023).

WP2 - Joint investigations of solar chromospheric and coronal activity

- Task 2.1: Chromospheric Signatures of Quiet Sun and Pre-Eruptive Configurations

The preliminary plan is to perform observations and data analyses of the morphology, dynamics and evolution of pre-flare activity; dynamics of spicules in polar and equatorial zones; sunspot morphology and evolution.

- Task 2.2: Multi-wavelength study of solar activity phenomena, their morphology and kinematics

This task includes 3 different types of data analyses: (1) Single event studies - data analyses of case studies of solar flares and filaments using both ground-based and space-based observations, in particular from NASA's Solar Dynamics Observatory and ESA's Solar Orbiter mission. The team members will investigate the energy release and particle acceleration in solar flares, both towards the

Sun as diagnosed in HXR data (e.,g., Solar Orbiter) as well those that are escaping the Sun and are observed in radio images and spectra (e.g., Low Frequency Array - LOFAR) as well as measured in-situ as SEPs at various locations in the heliosphere. (2) Analyses of KSO archive data (e.g., sunspots, filaments) available at KSO will also be explored in terms of occurrences, overall properties, association with other solar activity phenomena. (3) Other statistical studies - analyses on white-light (WL) flares, which are an enhancement of the visible continuum in a solar flare, and are mainly associated with large flares, will be carried out. The emission mechanism of WL flares has not been well understood yet. Some studies have suggested that their origin is accelerated non-thermal electrons and that a relatively strong magnetic field exists in the acceleration site (e.g. Watanabe et al., 2017). During the project we will perform literature review of all reported WL flares starting with the time period of the last solar cycle 24. We will collect and analyze data from available ground-based and satellite databases in order to compile a catalog and perform a statistical study of the observed WL flares.

WP3: Dissemination of the project results

- Task 3.1: Project web-site

In this Task, we will create a project-dedicated web-site (https://astro.bas.bg/project-sun/), populate it with general information, activities and project results, as well as support the overall maintenance.

- Task 3.2: Scientific dissemination

This Task will keep track of all team members' participation in solar/space weather-related conferences, University seminars and other scientific events. Copies and links to the materials will be freely provided via the project web-site.

The project started in mid-August 2023 with a total duration of 2 years. WP1-T1 and T2 are scheduled to take part during the first year, whereas WP1-T3 and T4 - during the second year. The activities in the remaining WPs are expected to be carried out during the entire duration of the project.

Expected impact

The proposed work is important and timely, as it will contribute significantly to advancing the research on the topic of early-stage solar eruption evolution and energetic particle acceleration. By making the needed connection between the observational parameters of the onset of eruptive filaments and flux ropes, EUV waves/shocks, and SEP acceleration efficiency, the proposed work will enhance our understanding of arguably the most important and consequential stages of solar eruption, which have not been studied in such detail in multi-wavelength analyses previously. This work will be relevant and necessary for interpreting observations from the upcoming NASA and ESA space missions Solar Probe Plus and Solar Orbiter, which will study activity in the solar corona with unprecedented detail at a proximity to the Sun never studied before. Identification of remotely observable coronal eruption parameters that control early particle acceleration will allow us in future work to develop predictive tools that will improve the current state of solar event forecasting. In addition, the project will produce a significant and consistently analyzed event sample, which may be used as catalogs in upcoming studies of solar eruptions, and may serve to identify additional predictive parameters of these eruptions in the future.

Furthermore, the joint efforts between the project team members will aid the successful establishment of solar monitoring at NAO-Rozhen and facilitate the overall visibility of the new instrument and the solar group at IANAO. The optical solar observations will also serve as a focal point for the multi-instrument research center for the Sun and space weather planned in IANAO, consisting of a suite of additional instruments: radio antennas (the planned LOFAR station, https://lofar.bg/), neutron monitor and a number of atmospheric monitoring devices.

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