Taras Shevchenko National University of Kyiv
Astronomical Observatory

Astronomy and Space Physics in Kyiv University

Book of Abstracts

International Conference
in part of the Science Day in Ukraine
dedicated to the 180th anniversary of the Astronomical Observatory of Taras Shevchenko National University of Kyiv, and to the 120th anniversary of the birth of Professor Serhiy Vsekhsvjatsky

May 27 – 30, 2025

Kyiv, Ukraine

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Place of the meeting (Web-conference on zoom-platform)
Astronomical observatory of Taras Shevchenko national university of Kyiv, Observatorna str., 3

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PLENARY SESSIONS

180 years of the Astronomical observatory of Kyiv University

V. Efimenko

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In 2025, the Astronomical Observatory will celebrate its 180th anniversary. In 2020, the observatory celebrated its 175th anniversary, and the staff prepared a monograph "175 Years of the Astronomical Observatory of Kyiv University", which outlines the history of the observatory, the development of scientific areas during its existence, biographies of directors, a list of defended doctoral and candidate theses, the history of the Department of Astronomy, lists of graduates who completed a full course of study by year, etc.

The changes that have occurred in the observatory over the past 5 years are described, in particular, changes in the structure of the observatory, staffing, measures to expand the topics of scientific research, and the provision of equipment for conducting scientific research. During this period, for various reasons, there was a decrease in the number of scientific workers, and scientists from other institutions were widely involved on a part-time basis to participate in competitions and to implement the won topics. This helped both to win new topics and to successfully carry them out. Important steps were taken to modernize the observatory's observation base, including the restoration of the operation of the observatory's observation station in the village of Pylypovychi.

Within the framework of the scientific school established in 1939 by Prof. S. Vsekhsvjatsky, the Observatory staff actively researches the complex of small bodies of the solar system (MTSS), which includes the discovery of new objects, observations and modeling.

The main goal is to solve both the fundamental problem of the origin and evolution of the Solar System and the applied problem of asteroid-comet hazard.

The existence of dark matter (DM) and dark energy (DE) is now reliably confirmed by observations, but elucidating the nature of these components of the Universe, which make up about 95% of its average density, remains the most pressing task of modern physics of fundamental interactions. The study of DE and DM is one of the key tasks of ambitious observational programs carried out by the international consortia CTA (Cherenkov

Telescope Array, now STAO) and LISA (Laser Interferometer Space Antenna). Since 2015, the KNU team has been a member of the CTA collaboration, the goal of which is to build and operate an array of new-generation gamma-ray telescopes with fundamentally new capabilities for registering ultrahigh-energy cosmic rays. Since 2022, KNU scientists have been participants in the LISA collaboration, the goal of which is to develop a space-based gravitational wave detector https://lisa.nasa.gov/.

The main astronomical instrument for solar studies is the horizontal solar telescope (HST). The uniqueness of the instrument is that it allows you to photograph the spectrum of almost the entire visible region (3800-6600 angstroms) in one exposure, where there are thousands of spectral lines that are formed at different heights in the solar atmosphere. This is important for a thorough study of solar activity and for environmental monitoring of pollution of the Earth's atmosphere. In 2021 The GST of the KNU JSC has been granted the status of national heritage (Resolution of the Cabinet of Ministers of Ukraine No. 1206 dated November 10, 2021).

In cooperation with GAO NASU, work on optical studies of the Earth's atmosphere was continued in two areas, which are included in international scientific programs: a) measurement of the total ozone content using a Dobson spectrophotometer; b) observation of sunlight scattered by atmospheric aerosols with a sunphotometer of the international network "AERONET".

Over the past 5 years, scientists of the Astronomical Observatory have continued their work in difficult conditions. Research results are published in prestigious scientific journals, scientific competitions of the National Research Foundation of Ukraine have been won. The international scientific conference "Astronomy and Space Physics at Kyiv University" is held annually.

120-th anniversary of Professor S. K. Vsekhsvjatsky

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This June marks the 120-th anniversary of the birth of S. K. Vsekhsvjatsky, an outstanding astrophysicist who worked at the University for more than 40 years as the director of the Observatory (1939 – 1953) and the head of the astronomy department (1939 – 1981). In 1939, the young scientist

moved from the Pulkovo Observatory to the Kyiv State University. Scientific research at the Observatory was historically related to astrometry, while the scientific interests of Vsekhsvjatsky S. K. were concentrated in the field of astrophysics, so there were certain changes in the subject of research.

Serhiy Kostiantynovych has a number of scientific discoveries recognized by the world scientific community. While still a student, he published an article in a German magazine about the age-related decrease in the integral brightness of short-period comets, later, the idea of the disintegration of comets, the composition of their icy nuclei and their origin, volcanism of planetary bodies S. K. Vsekhsvjatsky pays considerable attention.

Another direction of research is the dynamics of the solar corona, which was started in 1936 of the corona observations during a solar eclipse in the strip from the Black Sea to the Pacific Ocean. Many years of research have led to the conclusion of the solar corona expanding to the Earth's orbit and beyond. E. O. Ponomariov, graduate student of S. K. Vsekhsvjatsky in 1955 published the theory of the dynamic corona; it preceded the work of E. Parker (USA), in which the hydrodynamic expansion of the corona was called the apt term "solar wind".

The interaction of coronal plasma flows with the Earth's magnetosphere leads to geomagnetic effects, Vsekhsvjatsky experimentally discovered these things back in the early 40s of the last century, and forecasting of the state of the ionosphere and the passage of radio waves was successfully performed during the World War II.

Hypotheses about volcanism in the systems of the giant planets and the existence of rings in Jupiter, Uranus, and Neptune were brilliantly confirmed by the data of the interplanetary probes "Voyager" and brought widespread recognition to the scientist.

S. K. Vsesvjatsky was the founder of the scientific school "Research of Active Processes in the Solar System", which trained several dozen world-class professionals. The main idea that nothing is stable in the universe, everything is in continuous development, was actively promoted by Professor Vsekhsvjatsky S. K. and was introduced into research from auroras and geomagnetic activity to cosmogony theories.

High Energy Astrophysics research at the Astronomical Observatory of Kyiv University

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Research in the field of High Energy Astrophysics (HEA) has a long history at the Astronomical Observatory. Back in the last century, HEA became the cutting edge of astrophysical and astroparticle research, investigating astrophysical processes and phenomena at energies beyond the Standard Model of particle physics. The early stages of the evolution of the Universe, physical processes in the vicinity of relativistic objects, acceleration and non-thermal radiation of relativistic particles (cosmic rays) in astrophysical conditions, the nature and astrophysical manifestations of dark matter and dark energy have become available for study with the help of new space-born and ground-based missions (space missions of X-ray and gamma-ray astronomy XMM Newton, Chandra, INTEGRAL, Fermi, ground-based Cherenkov telescopes of the TeV range H.E.S.S., VERITAS, MAGIC, gravitational wave detectors LIGO-VIRGO, cosmic ray detectors Auger, Telescope Array, neutrino detector IceCube and many others).

In Ukraine, these studies have been conducted since the 1980s in scientific centers in Kyiv, Lviv, and Kharkiv, in particular, at the Astronomical Observatory of Kyiv University. Over time, the direction was recognized as a priority at the state level in accordance with the Inter-branch Coordination Plan for Fundamental Research in Cosmology, Relativistic Astrophysics and Gravity "Astroparticle Physics", approved by the NASU, MESU, and Kyiv University in 2005.

A significant increase in the level of research in the field of HEA and the involvement of students in it was facilitated by the opening of the Virtual X-ray and Gamma-ray Observatory (VIRGO) at the physics faculty of Kyiv University in 2006 - a scientific computer center for high-energy astrophysics to support research in the field of astroparticle physics and the use of space mission data in the X-ray and gamma-ray bands.

In 2015, Ukraine was accepted as a full member of the highly prestigious international CTA Consortium, which aims to build and operate an array of Cherenkov telescopes (Cherenkov Telescope Array, CTA) for the study of cosmic gamma-ray sources. Our University initiated and

organized Ukraine's accession to CTA and forms the basis of the Ukrainian scientific team in CTA.

In 2021, the Center for Collective Use of Scientific Equipment "Laboratory of High Energy Physics and Astrophysics" of Kyiv University was opened. The Center provides services to support research in the field of high energy physics and astrophysics by providing users with observational data obtained by modern X-ray and gamma-ray observatories

In 2024 Kyiv University, as part of an international consortium, won the European Infrastructure Grant HORIZON-INFRA-2023 ACME (Astrophysics Center for Multimessenger studies in Europe), which aims to provide wider, simpler and more efficient access to the best research infrastructures for Ukrainian scientists in the field of astronomy and astroparticle physics.

In the report, we present also the past and modern research results in the field of High Energy Astrophysics obtained at the Astronomical Observatory of Kyiv University.

The work was supported by the National Research Foundation of Ukraine under project No. 2023.03/0149

What we expect from the Comet Interceptor Mission?

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The Comet Interceptor mission, led by the European Space Agency (ESA) in collaboration with the Japan Aerospace Exploration Agency (JAXA), represents a pioneering step in cometary science. Unlike previous missions targeting known comets, Comet Interceptor will wait at the Sun-Earth Lagrange Point L2 for the discovery of a suitable dynamically new comet or an interstellar object entering the inner Solar System for the first time. The mission consists of a main spacecraft and two sub-probes, designed to separate shortly before the flyby and simultaneously observe the target from multiple perspectives. Its scientific payload will provide detailed information about the nucleus morphology, surface composition, dust and gas environment, and the interaction of the cometary coma with the solar wind. Comet Interceptor will offer an unprecedented opportunity to analyze

primordial material preserved since the formation of the Solar System or even from interstellar space. This will discuss the mission's concept, spacecraft configuration, scientific objectives, target selection strategy, and how it complements previous comet missions like Rosetta and Giotto. Additionally, it will outline the current development status and the timeline leading to its anticipated launch in 2029.

50 years of measurements of solar magnetic fields at the Astronomical Observatory of Kyiv National University: main tasks, results and prospects

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Measurements of solar magnetic fields began at the Astronomical Observatory of Kyiv National University in 1975, after the observatory received a solar magnetograph of the SibIZMIR design. The initiative to purchase this magnetograph and form a scientific group at the observatory that was to process observational data from this magnetograph belongs to the then director of the observatory, Pavlo Rodionovych Romanchuk. Testing the capabilities of this magnetograph in the conditions of the Kyiv astroclimate showed that this tool can be used to improve the forecasting of solar activity, but not to obtain significant scientific results that could be published in international journals. That is why, in parallel with magnetographic measurements, spectral-polarization photographic measurements were carried out at the observatory, which were of particular value because the horizontal solar telescope (HST) is equipped with a diffraction Echelle spectrograph. The main tasks were to estimate local magnetic fields in sunspots and flares based on a comparison of observational data in many spectral lines with different Lande factors, formation heights in the atmosphere, and temperature sensitivities. The main achievements in this direction can be considered the detection of very strong ("kilogauss") magnetic fields in solar flares (Sov. Astron. Letters, 1982, vol. 8), and later - magnetic fields in the range of 20-90 kG (Kinematics Phys. Celest. Bodies, 1993, Vol. 9), the construction of semi-empirical models of flares (10.1023/A:1005298827306; 10.1093/mnras/sty738 and others), as well as discovery of spectral signatures of 10^5 G fields (10.1016/j.asr.2022.04.012;

10.1093/mnras/stad1816). Promising scientific tasks that can be solved using observations at the HST of the AO KNU are the search and study of extremely strong magnetic fields based on Stokes diagnostics in an extended range of wavelengths (up to 15 angstroms and more) relative to selected magnetically sensitive lines (10.3390/universe10060262), as well as the continuation of visual measurements of the magnetic field strength modulus in large sunspots. In addition, the HST can be used to conduct environmental monitoring of pollution of the Earth's atmosphere.

Studies of Small Bodies of the Solar System at the Astronomical Observatory of Taras Shevchenko National University of Kyiv

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The study of small bodies of the Solar System (SBSS) at the Astronomical Observatory of Taras Shevchenko National University of Kyiv (AO KNU) was initiated by Professor Serhiy K. Vsekhsviatskyi. Today, these investigations are seamlessly integrated into the global scientific context through a comprehensive approach to the analysis of physical, optical, and chemical properties of small bodies, as well as through the study of non-stationary processes and the spatial and temporal variations in dust and gas characteristics within the atmospheres of various active objects.

The most valuable scientific and practical asset of our research is the large volume of comprehensive observations. Over the past five years, we have studied 45 comets, 5 active asteroids, 8 potentially hazardous asteroids, 2 Centaurs, and 8 satellites of major planets. At the AO KNU observing station in the village of Lisnyky, monitoring observations of 109 comets and 67 asteroids have been conducted to determine their precise positions. These data are of particular importance for orbit calculations and the identification of objects that may pose a potential threat to Earth. All astrometric positions have been published in the electronic circulars of the Minor Planet Center (MPC).

The core of our research lies in the dynamic integration of targeted observational data with their subsequent processing, analysis, and numerical modeling. This work is based on the use of modern numerical methods and algorithms, along with original software developed by the research team.

This integrated approach has enabled us to obtain results of international scientific significance.

The presentation highlights key findings from SBSS studies carried out at the Astronomical Observatory, which have been published in high-impact international journals and recognized by the global scientific community. These achievements are the result of fruitful collaboration with leading researchers and scientific institutions from around the world, combining cutting-edge methodologies with extensive experience in SBSS research. They open new prospects for further scientific developments and applications in the field of physical and chemical studies of Solar System bodies and their evolutionary processes.

Sensitivity of the redshifted 21 cm signal from Dark Ages to parameters of primordial magnetic fields

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We analyze the impact of decaying of primordial magnetic fields (PMFs) on the ionization and thermal history of the Dark Ages Universe ($30 \le z \le 300$), and its imprint on the spectral profile of the global signal in the 21 cm hydrogen line. The heating functions caused by decaying magnetic fields monotonously decrease after cosmological recombination; their amplitude depends on the strength B0 and spectral index nB of the initial power spectrum of PMFs. We computed the ionization and thermal history from the cosmological recombination up to the end of the Dark Ages epoch for a range of PMF parameters $0.05 \le B0 \le 0.5$ nG and $-2.9 \le nB \le 4$, and show the essentially distinguished thermal evolution from one in the ΛCDM model. We also show that the profile of the redshifted 21 cm hydrogen line is very sensitive to the PMF parameters from this range and can be used for their constraints.

This work is done in the framework of the project “Tomography of the Dark Ages and Cosmic Dawn in the lines of hydrogen and the first molecules as a test of cosmological models” (state registration number 0124U004029) supported by the National Research Foundation of Ukraine.

Particle acceleration at the post-adiabatic shocks in interacting supernova remnants

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When a supernova remnant (SNR) begins to interact with the dense material of a molecular cloud, its shock wave decelerates rapidly, and the post-shock temperature drops to levels that permit efficient cooling of the shocked plasma. At this stage, the shock enters the post-adiabatic phase of its evolution. During this phase, the internal structure of the SNR undergoes significant changes, particularly in the immediate post-shock region, at spatial scales relevant to cosmic ray acceleration. In our talk, we highlight the dynamics of post-adiabatic flows in SNRs, their impact on particle acceleration and non-thermal emission, and present supporting observational evidence in the radio band.

Magnetometry of the Solar Corona

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A key and crucial challenge in solar physics is to obtain empirical information on the magnetic field of the million-degree plasma in the solar corona. In this extended region of the solar atmosphere the explosive events can seriously impact the heliosphere and the Earth's magnetosphere. Understanding the physical mechanisms that trigger these events requires "measuring" the strength and geometry of the magnetic field that permeates the coronal plasma structures during the stable and unstable phases of their temporal evolution. This is an extremely difficult unsolved problem. First, we need to find observables of the solar radiation that are sensitive both to

the orientation and strength of the magnetic field. Second, we need telescopes and instruments suitable for measuring such observables. Third, we need to develop plasma diagnostic techniques capable of inferring the coronal magnetic field from the observations. The scientific goal of the talk is to review a novel contribution to these points.

Scalar perturbations from inflation in the presence of gauge fields

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Inflation is an important pillar of the standard model of cosmology. The main role played by this period of very rapid expansion before the hot big bang is that it leads to the amplification of vacuum fluctuations of the inflaton field and of the metric. This mechanism for the generation of cosmological perturbations is supported by observations of the cosmic microwave background and cosmological large-scale structure. Physical content of universe, in particular, presence of any additional physical field during inflation is reflected in the spectral properties of primordial perturbations generated at this stage.

We study how a generic Abelian gauge field (a possible precursor of the large-scale magnetic fields in the present Universe) affects scalar perturbations in the case when the gauge field interacts with the inflaton directly (by means of generic kinetic and axial couplings) and via gravity. The homogeneous background inflationary solution is defined by self-consistently taking into account the backreaction of the gauge field on the evolution of the inflaton and the scale factor. For the perturbations on top of this background, all possible scalar contributions coming from the inflaton, the metric, and the gauge field are considered. We derive a second-order differential equation for the curvature perturbation, capturing the impact of the gauge field, both on the background dynamics and on the evolution of scalar perturbations. The latter is described by a source term, which is quadratic in the gauge-field operators and leads to non-Gaussianities in the curvature perturbations. We derive general expressions for the induced

scalar power spectrum and bispectrum and then apply them to the simple well-known case of axion inflation without backreaction.

Relativistic Gravity and Cosmology in the New Millennium at the Astronomical Observatory of Taras Shevchenko National University of Kyiv

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I will review results of the astrophysics department in the field of relativistic gravity and cosmology. This scientific direction was formed in the early 1990s under the leadership of Dr Sci A.V. Mandzhos. Since 2000, significant efforts of the department have been devoted to extragalactic astronomy (theoretical studies of gravitational-lens systems, statistical studies of extragalactic objects and galaxy flows in connection with the problem of dark matter etc). In recent years, several cycles of theoretical work have been carried out within the framework of the General Relativity and its modifications (qualitative studies of solutions, singularities in GR).

RELATIVISTIC GRAVITATION AND COSMOLOGY

Searching for Polar Ring Galaxies using Deep Learning techniques

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Rare systems known as polar ring galaxies (PRGs) provide important information about the evolution of galaxies, especially the processes of gas accretion and the merging of early- and late-type galaxies. Even with their unique morphology, they are still hard to spot; most confirmed cases are discovered by visual inspection.

We propose a deep learning-based method for SDSS survey PRG candidate discovery. To create a high-quality training sample of strong and good candidates with SDSS imaging, we first visually inspected every known PRG catalog. Then, ensemble learning, segmentation, and augmentation techniques were used to expand the dataset; however, the most successful employed transfer learning with synthetic PRG images produced by GALFIT.

Our deep learning approach has resulted in the discovery of three PRGs (SDSS J140644.42+471602.0; SDSS J133650.48+492745.3; SDSS J095717.30+364953.5). Furthermore, we visually inspected the Catalog of the SDSS Ring galaxies at $z < 0.1$ (it is a part of a catalog by Vavilova et al. 2023) and discovered four PRGs among ~2,200 ring galaxies (SDSS J095851.32+320422.9; SDSS J104211.05+234448.2; SDSS J162212.63+272032.2; SDSS J104600.10+090627.2).

One of the discovered galaxies with transfer learning, SDSS J140644.42+471602.0, was studied with CIGALE software to determine its spectral energy distribution.

We created a new catalog with 179 PRGs that were visually inspected. This new dataset will help future theoretical research and CNN-based classification initiatives. Our findings demonstrate the effectiveness of integrating machine learning and synthetic data to identify uncommon morphological systems.

Dynamical Friction on Extended Objects in Ultralight Dark Matter

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Models of ultralight dark matter (ULDM) with particle masses in the range 10^{-23}-10^{-21} eV exhibit rich phenomenology and have been the subject of extensive study. These models successfully reproduce the large-scale structure of the Universe, as predicted by cold dark matter (CDM) scenarios, while also avoiding several small-scale issues inherent to CDM, particularly at galactic scales. A distinctive feature of ULDM is the presence of a central core formed by a Bose-Einstein condensate (BEC) of ultralight bosons.

Globular clusters, being spatially extended systems, are commonly modeled as Plummer spheres. Notably, the dynamical friction acting on such extended objects cannot be approximated as a simple sum of the individual frictional forces from constituent stars, due to the de Broglie wavelength of the dark matter particles being significantly larger than the typical interstellar separation within the cluster.

Motivated by the extended structure of globular clusters, we analyze the dynamical friction force acting on spatially extended probes—such as globular clusters and dwarf galaxies — moving through an environment of ULDM in the BEC state. Modeling the probe as a Plummer sphere of radius l_p, we derive analytic expressions for both the radial and tangential components of the force. In the limit $l_p \to 0$, these expressions reproduce the known results for a point-like probe. We find that the dynamical friction experienced by a Plummer sphere deviates significantly from that of a point mass when the ratio of its radius to the orbital radius is large, and also at high Mach numbers. Numerical simulations have previously shown that dynamical friction is suppressed for Plummer spheres compared to point-like objects of equal mass, potentially offering a resolution to the so-called timing problem. Furthermore, our analysis reveals a non-monotonic dependence of the friction force on the boson mass within the 10^{-23}-10^{-21} eV.

1. V.M. Gorkavenko, A.I. Yakimenko, A.O. Zaporozhchenko, E.V. Gorbar, Dynamical friction in ultralight dark matter: Plummer sphere perspective, e-Print: 2412.15428 [astro-ph.GA]

2. O.V. Barabash, T.V. Gorkavenko, V.M. Gorkavenko, O.M. Teslyk, N.S. Yakovenko, A.O. Zaporozhchenko, E.V. Gorbar, Analytic calculation of dynamical friction for Plummer sphere in ultralight dark matter, e-Print: 2504.06448 [astro-ph.GA]

Sensitivity of the signal of the first molecules of Dark Ages to the parameters of the primordial magnetic fields.

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The results of resent probes of intergalactic magnetic field (IGMF) with high-energy (~TeV) gamma rays emitted by distant blasars suggest that the strength of IGMF at cosmological scales (> 1 Mpc) is greater than ~10^{-16}-10^{-18} G. Since there is currently no widely accepted mechanism for generating magnetic fields in cosmic voids that fill most of the volume of the Universe during the formation of large-scale structures, it is natural to assume that IGMF originates from the primordial magnetic fields (PMFs) which arose in the early Universe as a result of some kind of magnetogenesis process. The strength of PMFs at cosmological scales should increase with redshift adiabatically, $B \sim (1 + z)^2$, with increasing effect on the ionized gas. Therefore, when approaching the last scattering surface, the interaction between PMFs and ionized gas in the intergalactic medium should be taken into account. Stochastic magnetic fields can heat baryonic gas in the early post-recombination Universe through mechanisms such as decaying turbulence and ambipolar diffusion. This heating is expected to accelerate the formation of the first molecules and enhance their spectral line signals during the Dark Ages. In this work, we investigate how the global emission signal from the first molecules H_2, HD, and HeH^+responds to key parameters of the primordial magnetic fields, including its strength, spectral properties, and helicity.

This work is done in the framework of the project “Tomography of the Dark Ages and Cosmic Dawn in the lines of hydrogen and the first molecules as a test of cosmological models” (state registration number 0124U004029) supported by National Research Foundation of Ukraine.

Rotating neutron stars in the macroscopic approximation

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In this report we present the macroscopic model for neutron stars, as a perfect liquid drop in equilibrium, in line of Tolman–Oppenheimer–Volkoff (TOV) equations derivations, for small azimuthal rotation frequency ω around the symmetry axis. The Friedman–Ipser–Stergioulas formalism for the Kerr metric in the Boyer–Lindquist coordinates [1] outside and the Hogan ones [2] inside of the neutron star (NS) is used in the leptodermic approximation $a/R \ll 1$, where a is a crust thickness and R is the radius of the NS [3]. The length interval squared

$$ds^2 = -e^{\nu}dt^2 + 2\tau\Omega\sin^2\theta dt d\varphi + e^{\lambda}dr^2 + r^2 d\theta^2 + r^2\sin^2\theta d\varphi^2$$

is determined by the Schwarzschild parameters ν and λ and Kerr rotation parameter $\tau = 1 - \left[(1 - r^2/R_S^2)^{1/2} - 3(1 - R^2/R_S^2)^{1/2}\right]^2/4$, $R_S = (3/8\pi E_0)^{1/2}$ is the Schwarzschild radius [3] ($c = G = 1$), E_0 is an internal value of the NS energy density. The surface gradient terms are taken into account through the energy density $E(\rho)$ for the macroscopic equation of state (EoS) as in the Extended Thomas Fermi (ETF) approach but with a strong gravitational field.

The angular momentum I and the moment of inertia (MI), $\Theta = dI/d\omega$, are macroscopically calculated in the adiabatic approximation. The adiabatic MI can be expressed as $\Theta = \Theta_{av}/(1 + G_{t\varphi})$ where Θ_{av} is the statistically averaged MI, and $G_{t\varphi}$ represents a correlation term involving the time–azimuthal coupling. The correlation term $G_{t\varphi}$ becomes significant

in a strong gravitational NS field which leads to a significant change of the Schwarzschild asymptote, in contrast to the statistically averaged MI Θ_{av}. The MI components Θ_{av} and $G_{t\varphi}$ are the sums of the volume and surface components obtained through the ETF energy density $E(\rho)$, $\Theta_i = \Theta_{iV} + \Theta_{iS}$ $(i = av, t\varphi)$ and $E = E_V + E_S$, where the subscript V shows the volume (~ the NS volume V) and S means the surface (~ the NS surface with the surface tension coefficient) terms.

The adiabatic condition, $\Theta\omega^2/2 \ll E$, can be used for applications to several NS rotation periods, $P \gg P_0 = 2\pi(\Theta/2E)^{1/2}$, where P_0 is their asymptotic boundary limit. For a range of well-known experimentally pulsars with the spin periods between about 5 and 3000 ms, the adiabatic approach is applicable, in good agreement with their observational data for the NSs. The internal densities used in these calculations are taken for the typical values of about a few times larger than that of nuclear matter. The radii are of the order of 10 km, and masses $1.2 - 2.1 M_{sun}$.

As perspectives, our analytical macroscopic approach can be used to account for the NS rotation frequency corrections to the TOV equations.

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Can we constrain a cosmological magnetic field via network analysis?

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The nature of magnetic fields detected on scales of galaxy clusters remains uncertain. Astrophysical mechanisms that generate magnetic fields often struggle to describe the observed field strengths, making scenarios

involving **primordial magnetic fields (PMFs)** particularly appealing. In such models, the additional pressure generated by magnetic fields can influence the formation of low-mass galaxies and affect their distribution within the cosmic web.

In this work, we present a novel suite of magneto-hydrodynamical simulations, **MAKITRA**, designed to investigate the effects of PMFs on the structure of the cosmic web. We model the distribution of galaxies in the simulations as a network and apply innovative methods of network analysis. Our results demonstrate that various network metrics can serve as sensitive probes of primordial magnetic fields at the nanogauss (~nG) level. These metrics offer constraints on PMFs that are comparable to those derived from Cosmic Microwave Background (CMB) observations.

Primordial black holes: observational constraints and gravitational-wave signatures

Olga Sergijenko for LISA Cosmology Working Group

In the recent years, primordial black holes (PBHs) have emerged as one of the most interesting and hotly debated topics in cosmology. We discuss the limits on the allowed PBH abundance set by various types of observations. We analyze and combine the latest developments in order to perform end-to-end calculations of the various gravitational-wave signatures of PBHs. We discuss their detectability with LISA, the first planned gravitational-wave observatory in space.

Nonassociative and nonmetric geometric and cosmological flows, solitons and quasicrystaline topological phases for dark energy and dark matter

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This contribution outlines the cosmological subprogram [1-3] of a research program on “Nonassociative and nonmetric geometric flows and application

in modern gravity, cosmology and quantum information theories". The program is for researchers at risk in Ukraine and supported by Fulbright USA-Romania and other International programs with participants from Germany, Greece, Kazakhstan, Romania, Türkiye, Ukraine and the USA.
In the first part, we summarize the main results and perspectives of the work [1]. A model of nonassociative and noncommutative gauge gravity for the de Sitter gauge group SO(4,1) embedding extensions of the affine structure group Af(4,1) and the Poincaré group ISO(3,1), was elaborated. In string theory, such nonassociative gauge gravity theories are determined by star product R-flux deformations. We analyzed physically important and geometric thermodynamic properties of new classes of generic off-diagonal cosmological solitonic solutions encoding nonassociative effective sources. Particularly, we focust on modelling by such solutions of locally anisotropic and inhomogeneous dark matter and dark energy structures generated as nonassociative solitonic hierarchies. Such accelerating cosmological evolution scenarios can't be described in the framework of the Bekenstein-Hawking thermodynamic formalism. This motivated a change in the gravitational thermodynamic paradigm by considering nonassociative and relativistic generalizations of the concept of W-entropy in the theory of Ricci flows. Finally, we computed the corresponding modified G. Perelman's thermodynamic variables and analyzed the temperature-like evolution of cosmological constants determined by nonassociative cosmological flows.

In the second part, we elaborate on nonmetric geometric flow theory and metric-affine gravity with applications in modern cosmology [2]. We derived nonmetric distorted R. Hamilton and Ricci soliton equations in such canonical nonholonomic variables when corresponding systems of nonlinear PDEs can be decoupled and integrated in general off-diagonal forms. This is possible if we develop and apply geometric and analytic methods involving corresponding types of generating functions and generating sources encoding nonmetric distortions. Using such generic off-diagonal solutions (when the coefficients of metrics and connections may depend generically on all spacetime coordinates), we modelled accelerating cosmological scenarios with quasi-periodic gravitational and (effective) matter fields; and studied topological and nonlinear geometric properties of respective dark energy and dark matter, DE and DM, models. As explicit examples, we analyzed some classes of nonlinear symmetries defining topological quasicrystal, QC, phases which can modified to generate other types of quasi-periodic and locally anisotropic structures.

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Manifestation of scalaron dark matter in f(R) gravity

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In f(R) gravity, the scalaron—a scalar degree of freedom arising from modification of General Relativity—could account for all dark matter in the universe if its mass lies in the meV–MeV range. We provide a detailed calculation of the scalaron's decay rate into two photons—a one-loop process of significant interest that has been the subject of discrepancies in the literature. We demonstrate that a direct evaluation of loop diagrams with appropriate regularisation eliminates the ambiguities inherent in methods relying on Jacobians from field redefinitions. Assuming the scalaron constitutes all of dark matter, we calculate the average cosmological background radiation produced by its decays into photons. We also estimate the contribution of primordial scalarons emitted in the hot early universe to the present dark matter density and find it to be negligible. Our results support all key aspects of the original scenario, in which scalaron dark matter behaves as a coherently oscillating field.

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Petrov type III electrovac space-times with one-way null electromagnetic field

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We consider electrovac space-times of Petrov type III with outgoing one-way null electromagnetic field as coupled system of the Bianchi identities and the Maxwell equations, and investigate compatibility of the first order equations and restrictions on the Newman-Penrose scalars. Such electrovac model describes how strong electromagnetic field may induce gravitational waves with transverse and longitudinal oscillations.

Penrose conjecture and instability of naked singularities in static spherically symmetric systems with scalar fields

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General relativistic static spherically symmetric (SSS) configurations in presence of the minimally coupled scalar fields (SFs) typically contain naked singularities at the center. We consider massless SF with power-law potential having the Coulomb asymptotic of the field for large values of the radial variable. The focus is on the linear stability of the SSS configurations satisfying the conditions of asymptotic flatness. We study monopole perturbations against SSS background under regularity conditions at the center and at spatial infinity; the problem is reduced to one Schrödinger-type equation with an effective potential having singularity at the center. Our numerical investigations reveal the existence of divergent modes of small perturbations at least for sufficiently small values of Q-parameter characterizing the strength of the scalar field at spatial infinity. This means instability of the configurations, confirming (in this particular case) the

well-known Penrose conjecture about the nonexistence of naked singularities. On the other hand, we have not found divergent modes of linear radial perturbations for sufficiently large Q.

Inconsistencies of nonassociative or nonmetric Einstein-YM-Higgs-Dirac theories and a cure for geometric flows and black ellipsoid, toroid and wormhole solutions in f(Q,R) gravity

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In the first part of the talk, I review a research program on "Nonassociative and nonmetric geometric flows and application in modern gravity, cosmology and quantum information theories" [1-4]. Fulbright USA-Romania and CAS LMU Germany supported the program for researchers at risk working and living in Ukraine. During 2020-2025, more than 20 papers of Q1 category were published by a team of authors from the USA, Ukraine, Greece, Romania and Türkiye.

The second part of the talk outlines the main results of [1-2]. We addressed the fundamental problems of formulating nonassociative and nonmetric Einstein-Dirac-Maxwell (EDM), equations, and study of important nonmetric gravitational, electromagnetic and fermion effects. Such issues have not been solved in modified gravity theories, MGTs. We elaborated on models of nonassociative or nonmetric EDM theory as respective generalizations of general relativity, GR, or f(Q,R,T,…) gravity theories. We develop our anholonomic frame and connection deformation method, AFCDM, which allows to decouple in general form and integrate (modified) gravitational and matter fields equations. New classes of generated quasi-stationary solutions were defined by effective sources with Dirac and Maxwell fields, nonmetricity and torsion fields, and generating functions depending, in general, on all space-time coordinates. For respective nonholonomic parameterizations, such solutions describe nonassociative/ nonmetric EDM deformations of black hole (BH) and cosmological metrics. Variants of nonmetric BH, wormhole and toroid solutions with locally anisotropic polarizations of the gravitational vacuum and masses of fermions, and effective electromagnetic sources, were constructed and analyzed. Such nonmetric deformed physical objects can't be characterized in the framework of the Bekenstein-Hawking paradigm if

certain effective horizon/ holographic configurations are not involved. We have shown how to define and compute nonassociative and nonmetric geometric thermodynamic variables using generalizations of the concept of G. Perelman W-entropy.

We conclude that our research program involves elaborating of new advanced geometric and quantum methods for constructing exact and parametric solutions of deformed EYMHD systems (we can add Yang-Mills-Higgs interactions). It has various perspectives applications to quantum gravity encoding nonassociative and nonmetric structures, which are asymptotically safe and renormalizable in the quasi-classical limits to GR [3,4].

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Similarities and singularities in relativistic static spherically symmetric configurations

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We consider common properties of static spherically symmetric (SSS) configurations in presence of scalar fields in General Relativity and SSS solutions in f(R) gravity under conditions of asymptotic flatness. The results of [1-6] are reviewed and further developments are outlined. The focus is on scalar fields that are minimally coupled with gravity and analogous structures in the Einstein frame of the f(R) gravity. Results on the qualitative behavior of SSS solutions in both cases (uniqueness, global

structure of solutions, stability etc) are presented. Typically, the SSS configurations have a naked singularity in the center. Particular attention is paid to systems with sufficiently large scalar field and/or scalaron masses, with applications to astrophysical objects in mind. The asymptotic parameters of the space-time metric at infinity are related with those near the center of the configuration. The results show remarkably similar properties for a number of scalar field/scalaron potentials. This work is supported by National Research Foundation of Ukraine under project No. 2023.03/0149.

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HIGH ENERGY ASTROPHYSICS

Multimessenger study of the A3558 and A3528 galaxy cluster complexes within the Shapley supercluster

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Galaxy clusters are among the largest gravitationally bound structures in the Universe and serve as hotbeds for high-energy processes, including mergers, shocks, and turbulence. They satisfy the Hillas criterion for particle acceleration, making them potential contributors to the observed flux of ultra-high-energy cosmic rays. However, the cosmic-ray population in galaxy clusters remains poorly understood, and direct detections of hadronic gamma-rays or neutrinos from these environments are still lacking.

The Shapley supercluster is the largest concentration of matter in the nearby Universe at a redshift of about 0.05. We model the thermal component of the intracluster medium using self-similar profiles and derive constraints on cosmic-ray parameters through the analysis of radio and Fermi-LAT gamma-ray observations in the core regions of the Shapley Supercluster, particularly A3558 and A3528 complexes. Additionally, we provide detection prospects for gamma-rays and neutrinos with current and future observatories. This study improves our understanding of cosmic-ray acceleration and propagation in large-scale structures, offering new insights into nonthermal processes in the Shapley supercluster.

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Short-term optical variability and quasi-periodic oscillations in TESS-observed blazars

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Short-term optical variability in blazars provides important information about jet activity and processes near supermassive black holes. In this study, we analyzed light curves of 16 blazars observed by the Transiting Exoplanet Survey Satellite (TESS), focusing on their variability characteristics and the presence of quasi-periodic oscillations (QPOs). We compared two photometric extraction methods: Quaver (fixed aperture) and TESSreduce (point-spread function and aperture). The Quaver method better preserved short-term variability and provided reliable variability metrics such as reduced chi-square, excess variance, and root-mean-square variability. The TESSreduce method produced smoother light curves and cleaner wavelet scalograms but occasionally resulted in underestimated variability. Using Quaver data, we detected QPOs with periods from 0.7 to 11 days using weighted wavelet Z-transform and Lomb-Scargle periodogram analysis. Shorter timescales may reflect relativistic Doppler effects, while longer periods could be related to accretion disk processes. Several blazars displayed multiple coexisting variability timescales. Variability parameters were also obtained through statistical analysis of flux histograms. Non-Gaussian distributions in some light curves indicated potential issues with data extraction. Future work will include red-noise simulations to assess QPO significance and cross-validation with ground-based observations (e.g., ZTF, ATLAS). These findings contribute to a deeper understanding of short-term optical variability and QPO behavior in blazars.

Unveiling Milky Way analogues: an X-ray study of isolated galaxies witn AGN

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Isolated galaxies represent unique cosmic laboratories that enable investigating nuclear activity without environmental effects related to galaxy interactions or dense large-scale structures. In our previous work, we hypothesized that isolation may serve as a key selection criterion for identifying Milky Way analogue candidates, as it allows the internal physical processes to dominate galaxy evolution over timescales of several Gigayears.

In this study, we performed a comprehensive X-ray analysis of a sample of 2MIG isolated AGN host galaxies at $z < 0.05$, using archival observations from Swift, NuSTAR, XMM-Newton, Chandra, and INTEGRAL. We systematized available data to determine their general X-ray properties, best-fit spectral models, supermassive black hole (SMBH) masses (estimated via central velocity dispersion), and examined possible parameter correlations.

Our results indicate that the isolation of galaxies in the nearby Universe does not significantly affect nuclear activity. This is confirmed by the diversity of accretion types and the absence of any advantage of one particular basic/compound spectral model. Based on the obtained X-ray characteristics and estimated SMBH masses, we propose UGC 10120, NGC 6300, and CGCG 243-024 as promising candidates for Milky Way analogue galaxies.

The analysis of spatial turbulence in ejecta of supernova remnants

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Turbulent processes in astrophysical plasma play a key role in energy dissipation, particle acceleration, and magnetic field amplification across

various cosmic environments. Modern-day astrophysical experiments in radio and X-rays already provides spatial resolution below arcsecond. It makes supernova remnants (SNRs) suitable objects for studying turbulence on scales covering several orders of magnitude.

We use autocorrelation-based analysis to study spatial and spectral properties of turbulence in SNRs based on observational data of Tycho's SNR. Also, we show how procedural noise functions, particularly Perlin noise with its controlled spectral properties, can efficiently generate turbulent fields that statistically reproduce key features of cosmic plasma turbulence.

This approach offers a new and promising tool for exploring parameter spaces in turbulence studies of SNRs and generating initial conditions for more detailed MHD simulations, potentially bridging the gap between theoretical models and observational constraints.

Spatially resolved X-ray spectral analysis of Si-, S-, and Fe-rich ejecta components in the Kepler supernova remnant

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Supernova remnants (SNRs) are among the most important natural astrophysical laboratories for studying the final stages of stellar evolution and the dynamics of supernova explosions. The remnant of Kepler's supernova - a young Galactic remnant of a Type Ia explosion observed in 1604 - provides a unique opportunity to examine these processes in detail. We present the results of a spatially resolved X-ray spectral analysis based on high-resolution observations from the Chandra X-ray Observatory. We constructed Doppler shift maps for prominent emission lines of Si (1.6–2.1 keV), S (2.3–2.6 keV), and Fe (6.0–7.0 keV), which enable a detailed reconstruction of the line-of-sight velocity distribution throughout the remnant. The obtained Doppler velocities, referenced to the rest frame of the remnant, provide information about the progenitor's initial internal structure, the anisotropy of the ejecta expansion, as well as asymmetries in the interaction between the shock and the surrounding interstellar medium.

A deep XMM-Newton look at photon-axion conversion in the Coma cluster

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Axion-like particles (ALPs) represent a theoretically robust extension to the Standard Model, arising organically from the Peccei-Quinn mechanism – a framework developed to address the strong CP problem in quantum chromodynamics. Beyond their theoretical importance in CP symmetry conservation, these particles stand as promising candidates for dark matter in scenarios involving extremely low-mass particles. These particles can couple to photons via a two-photon vertex, enabling oscillations in the presence of external magnetic fields. Such mixing is strongly enhanced in astrophysical environments like galaxy clusters, which combine vast kpc-lengths with coherent μG-scale magnetic fields, making them prime targets for indirect ALP searches.

This study constrains ALP properties by analyzing eight XMM-Newton observations of the Coma cluster's core (40'×40'). A total of 343.8 ks of XMM-Newton MOS observations were compiled and analyzed using a comprehensive spectral model accounting for astrophysical foregrounds, solar wind, cosmic X-ray background, instrumental features, and the thermal emission from hot ICM gas. The analysis sets 95% upper limits of exclusion on axion-photon coupling constant and axion mass $g_{a\gamma}<5\cdot10^{-13}\ GeV^{-1}$, $m_a<10^{-12}$ eV.

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Neutrino constraints on WIMP and superheavy dark matter annihilation/decay in the Shapley supercluster

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One of the primary approaches to uncovering the nature of dark matter is indirect detection, which searches for Standard Model (SM) particles produced in dark matter annihilation or decay. Among these messengers, high-energy neutrinos provide a unique and valuable probe. Unlike charged particles or photons, neutrinos propagate unimpeded over cosmological distances, preserving both directional and spectral information about their astrophysical sources.

We focus on modeling the expected high-energy neutrino spectral fluxes from dark matter annihilation and decay in galaxy clusters of the Shapley supercluster – one of the largest known mass concentrations in the Universe, located approximately 200 Mpc away and exceeding $10^{16} M_{\odot}$ in total mass. Using the open-source CLUMPY code, we calculated neutrino and gamma-ray spectra for different weakly interacting massive particle (WIMP) masses and annihilation/decay channels. The resulting spectral fluxes were compared to the sensitivities of current and future neutrino observatories, such as IceCube and KM3NeT, to constrain dark matter parameters.

Additionally, we considered superheavy dark matter (SHDM) particles with masses up to the Planck scale. Employing the open-source HDMSpectra code, we estimated neutrino spectral fluxes from SHDM decay and annihilation in the ultra-high-energy range $10^{15} - 10^{18}$ eV, relevant for detectors like KM3NeT. Despite the generally suppressed branching ratio of neutrino channels, their unattenuated propagation and clean astrophysical signature make them a promising channel for dark matter searches, particularly from regions with large dark matter overdensities.

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Search for magnetar-connected cosmic ray PeVatrons

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Luminous Supernova remnants (SNRs) and pulsar wind nebulae (PWNe) may be a promising manifestation of cosmic ray (CR) PeVatrons (E>1PeV=1e15 eV) and acceleration mechanism(s) at nonrelativistic and relativistic shocks. In the both cases we expect also high luminosities in synchrotron (from the radio- to the X-ray band) as well as in high-energy (HE, $\varepsilon > 100$ MeV) and very high-energy (VHE, $\varepsilon > 100$ GeV) gamma-ray emission. Both hadronic and leptonic scenarios are expected to contribute to the non-thermal emission from such SNRs and PWNe.

Central engines of luminous Supernova can be connected with fast-rotating new-born fast rotating magnetars with total rotational energy of order of 1e52 ergs and magnetic fields of order of 1e15 G. may serve as a cosmic ray EeVatrons (E>1EeV=1e18 eV).

In magnetar SGR1900+14 sky region a few VHE gamma-ray sources are observed: the unidentified extended Fermi-LAT HE source 4FGL J1908.6+0915e, the extended VHE H.E.S.S. source candidate HOTS J1907+091, and the point-like HAWC TeV source 3HWC J1907+085. As a potential counterpart SNR G42.8+06 is considered. In our previous publications we showed that recently discovered in magnetar SGR1900+14 sky region SNR candidates G043.023+0.762 and G043.070+0.558, at distances of 3.8 kpc and 2.7 kpc respectively, could also be potential sources of observed emission. But very recently the SARAO MeerKAT 1.3 GHz Galactic Plane Survey discovers unidentified extended source G43.025+0.777 with angular radius of $0.^{0}16$, centered on the magnetar SGR1900+14 position. We consider this new source as a SNR created by magnetar-connected Supernova outburst and build up a hadronic model of

observed multiwave (from radio- to VHE gamma-ray) emission from magnetar-supported luminous Supernova remnant.

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ASTROMETRY AND SMALL BODIES OF THE SOLAR SYSTEM

On the Interrelation between Long-Period Comets and Trans-Neptunian Objects

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This study addresses the possible interrelation between long-period comets (LPCs) and the largest trans-Neptunian objects (TNOs). The analysis unfolds in three stages. In the first stage, for each of 39 TNOs with absolute magnitudes $H \leq 4.1$ and a sample of 1 495 LPCs, we identify the number of orbital intersections N that occur within the perihelion–aphelion interval (q, Q) defined by the TNO's orbital plane (see Fig. 1). Next, to assess the statistical significance of any apparent comet–TNO associations, we replace each real TNO orbit with 205 fictitious orbital planes—systematically varying the inclination and ascending node within the same (q, Q) bounds—and recalculate the corresponding intersection counts n_i for each surrogate. Finally, by comparing the observed intersection counts N against the distribution $\{n_i\}$ via rigorous statistical tests, we determine whether the real TNOs exhibit a significantly greater frequency of cometary encounters than expected by chance. A negative result at this stage would indicate an absence of dynamical coupling between LPCs and TNOs, thereby obviating the need for further analysis. For any TNO yielding a statistically significant positive outcome, the second stage entails computation of the minimum orbital intersection distances (MOIDs) between all LPCs and each of the 37 TNOs. Particular attention is devoted to the same TNO(s) exhibiting a positive result in the intersection-count test. If this object also exhibits an excess of small MOID values relative to LPCs, that excess is rigorously quantified using appropriate statistical criteria.

Upon confirmation of a positive result, the study proceeds to its third phase. In this stage, the orbits of the long-period comets and the particular TNO in question are subjected to numerical backward integration over a timespan of several thousand years to assess their past dynamical evolution. Computational results indicate that only one TNO—2003 VS_2—yields a statistically significant excess. Within its perihelion–aphelion bounds (q, Q), its orbital plane is intersected by 46 LPCs, compared with an expected mean of 33 intersections ($\sigma = 5.65$). This excess attains a confidence level exceeding 0.95. Stage-two analysis further shows that 19 comets have

MOID values relative to this TNO not exceeding 0.1 au, whereas for the remaining TNOs the corresponding counts range from 2 to 13.

In the third phase, we performed backward numerical integrations of the orbits of 2003 VS_2 and a selection of long-period comets with well-determined trajectories using the MERCURY N-body integration package. The most notable outcome concerns comet C/1969 P1: approximately 77 years prior to the moment of the numerical simulation started, it approached 2003 VS_2 to within 0.22 au. Given the intrinsic uncertainties in the orbital elements of both the comet and 2003 VS_2, the actual closest-approach distance may have been appreciably smaller.

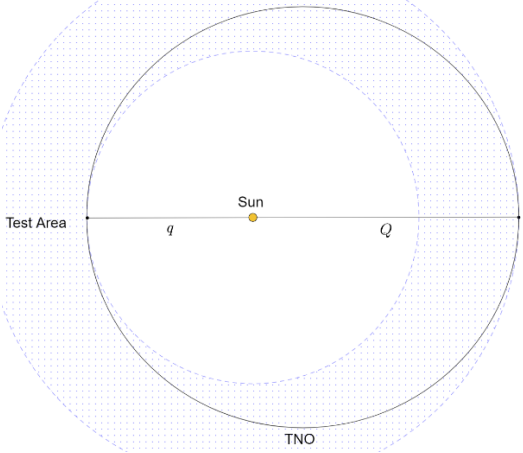

Figure 1. Schematic of the procedure for testing a TNO's orbital plane for intersections with LPC trajectories.

Evolution of Porous Cometary Dust–Ice Mixtures under Solar Irradiation

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In this study, we investigate the physical evolution of porous dust–ice mixtures representative of cometary surface layers under solar irradiation. Several types of porous structures were generated, including monodisperse,

polydisperse, and hierarchical configurations, to reflect a range of possible internal morphologies. Their geometrical properties, such as porosity, permeability and the mean free path of gas molecules, were characterized to understand how these factors influence gas diffusion through the medium.

Assuming that the porous layer is composed of a mixture of refractory dust and volatile ice, we simulated its structural disintegration driven by sublimation processes. The simulations enabled us to estimate the rate of mass loss and morphological evolution of the layer as functions of both the initial porosity and the construction method. Special attention was given to the emergence of clustering effects, in which sublimation of individual ice grains leads to reorganization or fragmentation of the structure.

Our results reveal critical threshold values of porosity and ice content beyond which the layer undergoes global disintegration. These findings provide new insights into the thermal and structural behavior of cometary materials and contribute to understanding mechanisms behind cometary activity.

Photometric monitoring of dynamically new comet C/2017 K2 (PANSTARRS)

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Minor ice-rich bodies are recognized as remnants of long-time evolution of the protoplanetary nebula. Among these objects comet nuclei, which reside in the outer region of the Solar system for a long time, are thought to preserve the most pristine internal composition since their formation. Being scattered into the inner part of the Solar system, many comet nuclei demonstrate considerable level of activity at large distances from the Sun, where the water ice sublimation cannot account for the observable comae. The activity pattern, which comets exhibit at large heliocentric distances, can shed light on primordial differences in their composition as well as potentially contribute to understanding the physical mechanisms driving the activity at large distances from the Sun.

In this report we present results of photometric monitoring of comet C/2017 K2 (PANSRARRS) in heliocentric distance range 15.3 – 5.1 AU before the perihelion passage and at distance of 5.23 AU after perihelion. The observations were conducted with 0.7-m AZT-8 Telescope at Lisnyky village (the Astronomical Observatory of Taras Shevchenko National University of Kyiv, Ukraine), 2.0-m RC Telescope of Peak Terskol Observatory (the International Center of Astronomical and Medico-Ecological Research, Ukraine), 1.3-m SkyMapper Telescope of the Siding Spring Observatory (Australia)*. Since most of the distant active objects, which have been observed previously, exhibit continuum dominated spectra, the broad band B, V, R, I filters and the the broad band u, b, v, r, z SkyMapper filters were used for observation of C/2017 K2. The images serve to estimate some global characteristics of the comet coma: the Afro parameter as a proxy for the dust production rate, the color indices of the dust coma and their spatial variation over the coma as well as the change in the normalized reflectivity gradient of the reflected solar radiation with distant from the Sun.

*The observations with the SkyMapper Telescope of Siding Spring Observatory (Australia) were supported by Grant of Ukraine-Australia Research Fund.

SkyMapper Active Asteroids and Comets Survey: Main Belt Comet P/2023 JN16 (Lemmon)

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We present the results of broadband observations of main-belt comet P/2023 JN16 (Lemmon) conducted in the frame of the SkyMapper active asteroids and comets survey program in 2024. The telescope's advanced 1.35-meter modified Cassegrain optics has an f4.79 focal ratio, making the system highly efficient as a survey instrument. At the heart of the telescope is a unique digital camera designed and constructed in house by Australian National University technicians which has a 268 million pixels (0.498″/pix) to capture a region of sky 32 x 34′ x 17′.

The comet P/2023 JN16 has a low eccentricity orbit (e = 0.147) in the ecliptic plane (i = 3.703°) at the outer boundary of the main asteroid belt (a = 2.695). The observations were made from the late July to September (12

nights), before perihelion on December 30, 2024. The SMSS (SkyMapper Southern Survey) *gri* filters were used for photometry. SMSS DR4 catalogue was used as a source of the reference solar analog stars.

The observations showed very low dust activity of the comet with $Af\rho$ about 1 cm. Color indices and spectral gradients are estimated. The estimated radius of cometary nucleus is less than 0.4 km. Preliminary analysis shows that P/2023 JN16 activity were caused by stream of dust particles from the nucleus which formed optically think straight short dust tail (about 65″ - 75″).

The work was supported by Grant of Ukraine-Australia Research Fund.

The approach of asteroid 99942 Apophis to the Earth in April 2029

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The asteroid Apophis was discovered in 2004. Its size is about 350 m. And a years later it was determined that in 2029 it should approach the Earth at a record close distance (geocentric distance Δ should be about 38,000 km). This will be the first calculated approach of an asteroid to the Earth, visible to the naked eye.

Based on the updated orbital elements on the epoch of May 5, 2025, the parameters of the approach of asteroid 99942 Apophis to the Earth in April 2029 were calculated. For Kyiv, Apophis will rise above the horizon on April 13 at 17.20 UT in the southeast with a brightness of 3.3^m. At this time, its geocentric distance Δ will be about 110,000 km. Two hours later, the brightness will increase to 2.4^m at Δ = 72,000 km. The minimum geocentric distance of 38,400 km will occur at about 21.30 UT with the brightness of 1.6^m. Apophis will set behind the horizon in the northwest at about 23 UT with the brightness of 3^m. But already on April 14 at 2.20 UT it will rise again in the northeast with the brightness of 7^m. Then the asteroid will not be visible to the naked eye in a light sky.

These parameters of the approach differ little from the first calculations. This indicates little changes in the elements of the asteroid's orbit. Therefore, it can be argued that Apophis will bypass the so-called "keyhole" with a width of only 600 m at Δ = 36,823 km. When passing through the

"keyhole" in 2029, the asteroid's orbit should change so that it can collide with the Earth as early as 2036.

An improved model of analytical computation and risk assessment for encounters of circumterrestrial vehicles with meteoroid streams

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The given work is a sequel of investigations of the interacting circumterrestrial space vehicles with space particles transecting earth orbit, and the risk assessment of a satellite damage, or its complete destroying as a functional unit. In previous researches we demonstrated the results of computation of risk assessment of interaction of sporadic meteor background particles with a satellites of known effective surface square, and estimations of their damage risk. Particularly, earlier we analyzed the fact of decapsulation of a block of a satellite "Ocean-O" to be made in Ukraine, during an activity of Leonids meteor shower, namely on 18 November 1999. Also, at this stage, we took into account a potential danger from the near-earth debris particles [1]. Later, we presented preliminary risk assessments of influence of meteor streams as alternative once to sporadic meteor background and space debris particles [2].

In the given report we present the results of the complete analytical model of encounter risk assessment and damage extent estimation of near-earth vehicle with a space particle, partly from a meteor shower. As a damage extent we considered such parameters of an explosive crater on a satellite surface as its depth and diameter. The theory of crater creations by Epic to be well known in meteor astronomy was used. At this, the elements of a critical damage – craters of the depth more than 2 mm were selected; and the corrosion effects, especially on the solar battery surfaces – 10 mkm were taken into account. As a mathematical model of a meteor stream the following parameters are considered: spatial density of meteoroids in the stream as a function of their masses, geocentric velocity of a meteor stream, and the distribution of particles in the stream on masses. Obviously, the physical characteristics of both meteoroids and a satellite surface such as their densities and strength coefficients must be taken into account additionally. For low height vehicles the factor of their temporary screening by the earth and earth's atmosphere from the active meteor stream caused by the satellite rotation along a circumterrestrial orbit is also taken into account. For the satellites of primitive shape the calculation of their

effective surface squares is proposed as a composition of 3-D geometric figures – spheres, planes, parallelepipeds, cylinders etc. The example for calculation of interaction of a hypothetic satellite with the most huge meteor showers is proposed.

[1] Kruchynenko V.G., Kozak P.N. (2021) Explosive craters on a surface of space vehicles formed by meteoroids and space debris particles. Kosm. Nauka & Technol. 7, 5/6, 71-74.

[2] Kozak P.M. (2024) Estimation of the probability for damaging an artificial satellite from stream and sporadic meteors. Abst. book of XXIV Gamov International Astronomical Conference "Astronomy and Beyond: Astrophysics, Cosmology and Gravitation, Astroparticle Physics, Radio Astronomy, Astrobiology and Genetics", 19-23 August 2024, P. 42.

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The artificial intelligence using for the creation of software for meteor astronomy

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This work presents the authors' first experience in applying artificial intelligence (AI) for the creation of software for meteor astronomy. We demonstrate the successful use of an artificial neural network for the automated generation of software code intended for modeling the trajectories of meteoroids and, consequently, for predicting the landing sites of meteorites on the Earth's surface. To achieve this goal, we used a method of software code generation by AI based on a text query that describes the main goals, methodology, input data and output requirements. In particular, using AI, we generated and adapted functional software code in the VB6 (Microsoft Visual Studio 6.0), which makes it possible to calculate the trajectories of bolides based on observations. The AI-generated code was tested on real observational data of bolides for which meteorite falls were recorded. As an example, AI was trained to generate VB6 code for calculating trajectories using the fourth-order Runge-Kutta method, which considers parameters such as initial velocity, entry angle, mass, density and

shape of the meteoroid, as well as geodetic coordinates and altitude of the initial point, velocity and wind azimuth. The possibility of using the Monte Carlo method to calculate errors is provided. The software allows for the modeling of dispersion ellipses, taking into account the fragmentation of the meteoroid in the atmosphere, or calculates geodetic coordinates (WGS-84) for individual fragments. The calculation results are displayed in a user interface and stored in data arrays for further analyses, including graph plotting and data export. The obtained results are used to predict likely meteorite landing sites, demonstrating the effectiveness of the developed method and the potential of AI in solving problems in meteor astronomy.

Plans and prospects for the meteor astronomy development at the Taras Shevchenko National University of Kyiv

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Modern methods of meteor astronomy are an important addition to the existing tools for collecting and analyzing of astronomical data. However, the effective obtaining and processing of observational data, with subsequent accurate determination of meteor bodies characteristics, requires constant improvement of both optical instruments and observation techniques, as well as methods for processing the obtained information. In 2025, the research group of the Astronomical Observatory of Taras Shevchenko National University of Kyiv launched a project to modernize video-spectral observations of meteors in order to increase the efficiency of observations and the accuracy of the obtained results. This project envisages the creation of a meteor complex using modern technologies, taking into account the experience of meteor observations, in particular, obtained in Kharkiv using the AVSMP.

The key element of the project is the modernization of the video-spectral complex (VSC) through integration with the RMS (Raspberry Pi Meteor Station) platform, which is open-source software from the Global Meteor Network. RMS is designed for automated meteor detection, analyzing their trajectories, and uploading the results to cloud servers for further scientific analysis. The advantages of the chosen approach are: the compactness of the

station, which allows placing all components, including the video camera in a sealed box; cost-effectiveness, due to the use of the Raspberry Pi microcomputer; and high-resolution of HD IP cameras (1280 x 720), providing a greater sky coverage area with astrometric precision comparable to analog cameras. The autonomous operation of the station is ensured by both energy independence and the ability to upload data and update software via the Internet. RMS automatically identifies meteors based on the received data, calculates atmospheric kinematic parameters and heliocentric orbits, which allows to quickly obtain scientifically significant results.

On the other hand, various types of video cameras equipped with diffraction gratings of 500-600 grooves/mm for spectral observations of meteors will be installed at the RMS. Thus, as a result of processing the observation material with the help of this meteor patrol, the kinematic parameters of the particles motion in the Earth's atmosphere (velocities, linear altitudes, etc.), the coordinates of the radiant on the celestial sphere, the elements of the heliocentric orbits of meteoroids, their chemical composition, sizes and masses will be obtained. All the results of positional, photometric and spectral observations, measurements and calculations will be formatted in the form of a database containing: a catalog of video observation files, a catalog of kinematic atmospheric parameters and elements of the heliocentric orbits of meteor bodies; a catalog of identified emission lines in meteor spectra with determined values of the effective temperature and concentration of atoms of chemical elements in the meteor plasma.

Observation of the occultation of the star TYC 1318-01031-1 by the asteroid (52) Europa on September 9, 2020

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We present the observation and analysis of the occultation of the star TYC 1318-01031-1 by the asteroid (52) Europa, recorded at multiple locations along the event's path. During data processing, an own method

was employed to integrate observations from various distant sites, where results were independently obtained at each location. Photometric light curves of TYC 1318-01031-1 were analyzed to determine the precise moments of occultation onset and conclusion at each observation site. Further processing utilized the proposed method for consolidating occultation data from widely separated points. This approach proved effective in analyzing multi-site observations and highlighted the potential of amateur observations in reconstructing asteroid shapes. The results demonstrate a high-quality reconstruction of the shape and size of asteroid (52) Europa, consistent with models available in the Database of Asteroid Models from Inversion Techniques (DAMIT).

On the digitization and recalculation of the results of Poltava latitude observations with the ZTL-180 zenith telescope in the Hipparcos catalog system

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The Poltava Observatory is worldwide known for its long-term observations of stars to determine changes in latitude and polar coordinates. Although the International Earth Rotation Service stopped using astrooptical observation methods in 1988, the results accumulated over the century continue to be used today to determine polar motion parameters changes and for other geodynamic purposes.

Among such data are the results of zenith stars observations with the zenith telescope ZTL-180 during 47 years (1967-2014). The program of these observations changed over time, but in its most complete form consisted of six groups of five stars. Among them were two bright stars αPer and ηUMa (Hipparcos catalog numbers 15863 and 67301), which were observed throughout the specified period both at night and during the day. Other stars are of low brightness, they could be observed only at night, each of them had a different duration of observations during 1967-2007. Three groups of stars are temporally related to both αPer and ηUMa.

Since 1993, all current observations have been digitized immediately. The results of all previous observations of bright stars were firstly digitized

and were actively used in research, since they are continuous and long-term. These digitization works were carried out with our participation.

In 1999, the observatory received "The Hipparcos and Tycho Catalogues" (1997). Since then, we have been working on recalculating the results of latitudinal observations of zenith stars with ZTL-180 in the Hipparcos catalogue system (M.F. Tyschuk).

Low-luminosity stars could be observed for about 6 months a year. Therefore, their latitudinal series were of much less importance. But we initiated work on digitizing all the results of observations with ZTL-180 for further use (Tyshchuk M.F.). We have now fully digitized most of the observation results. Here are the data for three groups related to the star αPer (15471 observations): № is star number according to the Hipparcos catalog, P is observation period, n is number, φ_m is mean latitude (49°36′), σ_p is standard deviation from the individual latitude curve constructed from the coordinates of the pole (after rejecting results with latitude deviations >0.6″).

1st gr., №	14632	15444	15863	16210	16986
P	1967-2007	1984-2000	1967-2014	1967-1999	1984-1999
n	2822	1066	5841	1981	823
φ_m(″)	14.776	14.978	14.884	14.902	14.598
σ_p(″)	0.193	0.195	0.208	0.189	0.198
4th gr., №	18353	19167	19727	20070	20370
P	1984-1994	1984-1994	1984-1994	1984-1994	1985-1994
n	284	327	283	310	244
φ_m(″)	14.537	15.158	14.561	15.141	15.026
σ_p(″)	0.212	0.221	0.205	0.226	0.199
5th gr., №	27196	28162	28562	29869	30520
P	1984-1994	1984-1994	1984-1994	1984-1994	1984-1994
n	308	281	299	277	325
φ_m(″)	14.907	14.520	14.535	14.750	14.612
σ_p(″)	0.189	0.187	0.214	0.189	0.166

Photometry-Dependent Astrometry of Comet C/2023 A3 (Tsuchinshan-ATLAS)

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Unlike asteroids, comets have complex morphology and a variable level of gas and dust activity, which complicate the precise determination of their orbits. Physical processes in the cometary nucleus cause the formation of an asymmetric coma and tail, resulting in a photocenter shift in the tailward direction. The magnitude of this displacement, obtained through the processing of observational data, strongly depends on the aperture size, the chosen brightness profile model, and other observing conditions. This situation presents additional challenges in orbital modeling, as observational biases and nongravitational forces are difficult to disentangle: modeling errors in nongravitational effects can manifest as systematic residuals in the coordinates, while observational biases may be misinterpreted as signatures of nongravitational acceleration.

This study presents astrometric results derived from the processing of CCD observations of comet C/2023 A3 (Tsuchinshan–ATLAS) obtained from three observatories: 954 — Teide Observatory (Spain), Q55 — Siding Spring Observatory (Australia), and 585 — Kyiv Comet Station (Lysnyky, Ukraine), using telescopes equipped with photometric filter systems. Topocentric equatorial coordinates of the comet were derived using various apertures and three centroiding methods: Gaussian fitting, Moffat fitting, and center-of-mass. For each observatory, the positional accuracy was evaluated by comparing the derived coordinates with the JPL HORIZONS ephemerides. The residual differences between observed and ephemeris positions indicate a clear photocenter shift, the magnitude of which depends on the comet's orbital position, the aperture used, and the brightness profile model. The analysis also revealed statistically significant differences between several photometric bands.

Additionally, the study includes a comparison of available observational data from the MPC database for several bright comets with ephemerides from the HORIZONS service. Detected systematic deviations in the residuals of right ascension and declination coordinates show a correlation with changes in comet brightness, indicating that the standard Marsden–Sekanina–Yeomans non-gravitational acceleration model, used in

HORIZONS for orbit calculations, does not account for the dynamic features of comet motion at certain orbital segments. The obtained results highlight the importance of selecting an appropriate method for determining the photometric center of a comet to construct accurate orbits and can be used to refine models of non-gravitational motion for active comets.

About Possible Manifestations of Geodynamic Events from GNSS Observation Results

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Global Navigation Satelite System (GNSS) is an important source of empirical information for modern astrometry and geodynamics. GNSS observation data are used to determine the parameters of the Earth's rotation, plate tectonics, crustal deformations, etc. The high accuracy of these determinations allows recording geophysical signals of unknown nature. Below we provide an example of such signals.

Synchronous jumps of N-components of local coordinates of several GPS stations were detected according to the EUREF Permanent GNSS Network (EPN) data for the epoch 2014.0. These stations are Golosiiv, Mykolaiv, Poltava, Kharkiv and Ankara. In the second half of 2013, synchronization of the phases of N-components occurred at these 5 stations. The 4-month local minimum at the moment of 2014 was followed by their coordinated jump-like growth. This may be a consequence of some geophysical factor. The listed stations are located in the sector with coordinates (logitude L=30-36°E; latitude F=40-50°N). In order to evaluate the scale of this phenomenon, the behavior of the N-components for three Polish stations was additionally examined: Jozefoslaw, Krakow and Wroclaw, located in the sector (L=17-21°E; F=50-52°N). A short-term disturbance is observed for the Krakow station (L=19.9°E; F=50.1°N) for the moment around 2013.5, which can be attributed to the influence of the sought factor. A weaker signal is characteristic of the Wroclaw point (L=17.1°E; F=51.1°N), and for the Jozefoslaw point (L=21^0E; F=52.1^0N) the peculiarities in the behavior of the N-component are imperceptible. Disturbance is also not detected for the N-component of the Pulkovo station (L=30.3°E; F=59.8°N). These facts show to the presence of a global source

of disturbances, however, its manifestations are not ubiquitous (F<50°N) and not simultaneously, but probably drift from west to east.

Solar and geomagnetic activity phenomena, as well as the geomagnetic jerk (GMJ) phenomenon that occurred just at the beginning of 2014, were considered as possible sources that could have caused the N-component jump. It is shown that a noticeable increase in the solar activity index (SAI) occurred 3 months before the N-component jump, which does not exclude the interrelation of these phenomena. The coincidence of the epochs of the N-component jumps and GMJ may also not be accidental. GMJ is the phenomenon of abrupt changes in the second derivative with respect to time of the secular drift of the Earth's magnetic field. Jerks are not globally simultaneous: GMJ epochs for different regions can vary up to 1–2 years. It is also known that GMJ significantly affects the parameters of the free core nutation of the Earth (FCN). Moreover, the change in the amplitude and phase of FCN also occurs abruptly. The primary source of GMJ is considered to be processes occurring in the liquid core of the Earth. The causes of generation of GMJ processes are still a subject of research. The influence of external sources is not excluded: for example, the solar wind. To explain the activation of the Earth's core, it would be appropriate to use the universal theory of planetary processes developed by Barkin Yu.V. The theory is based on the gravitational mechanism of forced displacements of the core relative to the Earth's mantle, caused by the influence of surrounding celestial bodies. Such shifts can be a source of both changes in the core rotation parameters and endogenous energy release at the core-mantle boundary, activating mantle plumes. On the Earth's surface, these phenomena will cause changes in the magnetic and gravitational fields, as well as short-term deformations of the Earth's crust, which are recorded as jumps in the local coordinates of GPS stations.

The study of sporadic signals recorded by GNSS observations can complement the picture of interconnected and interdependent geodynamic processes.

Improving observation efficiency: experience in modernizing the focusing and coma correction systems of the AZT-8 telescope

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One of the key challenges in modern astronomical research is the need to technically upgrade and modernize existing telescopes to meet current scientific and educational demands. Worldwide, modernization of optical telescopes often includes the installation of advanced light detectors, optical system replacements, autofocus units, field correctors, and integrated software systems.

Ukraine is no exception: many universities and research institutions operate historically significant telescopes that retain scientific potential but require substantial upgrades to remain competitive and functional in contemporary settings. Such modernization efforts are an investment in the future of Ukrainian science, allowing aging telescopes to be transformed into modern research instruments and contributing to their relevance on the international scientific stage.

A critical factor in improving image quality is the implementation of automatic focusing and the correction of optical aberrations. The optical-mechanical unit developed for the AZT-8 telescope addresses these issues by enabling real-time focusing and coma correction.

The modernization significantly enhances the telescope's key parameters. The resulting optical system achieves higher light-gathering efficiency, which is essential for observing faint celestial objects and reduces exposure times. It also expands the telescope's angular field of view without compromising angular resolution.

The optical-mechanical unit is compatible with commercially available compact devices, including CCD-based instruments, and supports a wide range of astronomical applications such as astrophotography, spectroscopy, and photometry across a broad spectral range.

Modernization of the Fast Pointing System of the AZT-8 Telescope

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A fast and precise pointing system is crucial for modern astronomical observations, especially when tracking transient events, monitoring moving objects (such as asteroids, satellites, and comets), or enabling remote robotic operations for educational and scientific purposes. The original pointing system of the AZT-8 telescope, based on an analog control panel and outdated drive motors, significantly limited the accuracy, smoothness, and remote accessibility of telescope operations. These limitations hindered the telescope's usability in current scientific research and educational settings.

- To address these issues, a comprehensive modernization project was implemented, which included the following upgrades:
- Replacement of legacy motors with stepper motors featuring software-controlled speed and braking;
- Development of a Wi-Fi-based interface for wireless remote control;
- Integration with modern software for precise pointing and positioning.

The new system allows for dynamic adjustment of pointing speed in real time, delivers smooth and accurate motion, and supports remote telescope control via a local network or internet. This functionality is particularly valuable in educational contexts, enabling students and researchers from different locations to access and operate the telescope remotely.

The modernization has significantly improved the performance and operational flexibility of the AZT-8 telescope, expanding its capabilities for both scientific research and astronomy education.

A Systematic Approach to Exoplanet Validation: New Findings from TESS Sector 85 Observations

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We present a comprehensive analysis of transit signals from 12,993 stars in TESS Sector 85, combining photometric validation with physical parameter estimation. Our pipeline identified 121 exoplanet candidates and 10 confirmed exoplanets, along with 8 previously unclassified signals. Six of these were attributed to nearby eclipsing binaries and one to an asteroid, while two new potential exoplanet candidates (TIC 198280919 and TIC 417644279) passed all false-positive tests. The candidate TIC 417644279 exhibits a radius r = 2.03 Ґ} 0.10RJ and orbital period P = 10.88 days, although the semi-major axis could not be determined due to missing log g data for the host star. TIC 198280919 shows the planetary characteristics with r = 0.25 Ґ} 0.01RJ, a = 0.054 Ґ} 0.004AU, and P = 4.63 days. Both candidates have been submitted to AAVSO for variability index assignment and await official designation in exoplanet catalogs (such as TOI or CTOI). Using the Transit Least Squares (TLS) algorithm, we derived physical parameters for 133 systems, including orbital periods P, semi-major axes a, planetary radii r, stellar masses M, and transit depths δm. The sample is dominated by Hot Jupiters and Neptunes, reflecting TESS's sensitivity to short-period giants. Our validation pipeline, designed to emulate NASA's automated detection frameworks, successfully distinguished astrophysical false positives from genuine planetary signals. Current work focuses on full automation of this pipeline for future TESS sectors and other transit surveys.

Derivation of a formula for predicting Perseid meteor shower activity

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Perseids are a relevant and interesting topic for research that helps to better understand the behavior of the atmosphere over the years.

Data for 3.5 solar cycles were collected and analyzed. We took the value of the number of sunspots for August, and the illumination of the Moon and ZHR for the night of August 12-13, which is the peak of the meteor shower. We determined that the Moon significantly shines meteors starting from 50% illumination and calculated the correlation coefficient according to Pearson's formula.

To analyze the correlation between ZHR and solar activity, we chose the interval of the 24th solar cycle of 2009-2019 and determined the presence of a negative correlation. The complex interaction of factors leads to the observed frequency of the meteor shower.

The formula we derived allows us to predict the ZHR value of the Perseid meteor shower using indicators of the number of sunspots and the percentage of illumination of the moon.

The calculated forecast indicators of the ZHR give us reason to assert that in the next 9 years, by the end of the solar cycle, the Perseid meteor shower will be very active due to a decrease in solar activity. Our research can be used in further studies of cosmic phenomena and in observing changes in the Earth's atmosphere.

SOLAR PHYSICS, SOLAR ACTIVITY AND ASTROBIOLOGY

Semi-empirical models of exploding granules: preliminary results based on LTE inversion

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We present the results of modelling the features of the granular structure of the quiet solar atmosphere. We used the results of spectral observations in the Fe I 5576 Å line of a region located at the center of the solar disc, obtained with the SST telescope (Canary Islands, Spain). Semi-empirical models of exploding granules were constructed using the SIR inversion code. Based on the retrieved values of the vertical velocity and density, we calculated the horizontal velocity components in the regions of exploding granules.

The height stratification of the thermodynamic and kinematic parameters of the atmosphere in these areas was investigated. The resulting models reveal a pressure increase within dark dots located at the centres of these granulation structures. These dark dots subsequently evolve into new intergranular lanes. Localized increases in temperature, pressure, and vertical velocity are observed in small regions on the edges of some of these granules, which may indicate the formation of high-speed flows – jets.

Estimation of cycle 25 parameters based on the increase in solar activity during the growth phase

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Solar activity is an important environmental factor. It is closely related to a number of geomagnetic phenomena, largely determines space weather, and has a profound impact on the space and terrestrial environment. Having reliable forecasts of solar activity, we can assess these indices and the course of the natural processes associated with them. It should be noted that today there is still no sufficiently developed theoretical model for predicting

solar activity for periods from several months to several years. Therefore, mathematical and statistical methods are used for practical forecasting for these periods. In addition to the height of the 25th cycle of activity, the assessment of the parameters of the current cycle is also of considerable interest, namely: the duration of the growth phase of the cycle and the total duration of the 25th cycle of solar activity.

The method of constructing the dependences of the cycle height, the duration of the growth phase, and the duration of the cycle on the rate of increase in activity based on the known data of the 24 previous cycles was used. The determination of the coefficients of linear and polynomial dependencies was performed using the OriginPro 8 software environment. The work refined the previously calculated forecast of the 25th cycle, estimated the duration of the growth phase and the full duration of the 25th cycle, taking into account the average rate of increase in activity in the growth phase of the 25th cycle and the obtained dependence coefficients.

The constructed dependencies made it possible to refine the amplitude of the 25th cycle, which is Wmax 25 = 156.3 ± 14.4 units (the previously obtained cycle amplitude was estimated within 150-160 units), as well as to calculate the duration of the growth phase and the full duration of the cycle. The duration of the growth phase and the full duration of the cycle were calculated using linear and polynomial dependencies. The values obtained are close to each other.

The forecast of the amplitude of the 25th cycle was refined, the duration of the growth phase of the cycle and the duration of the 25th cycle of solar activity were calculated. It was found that the dependence of the duration of the growth phase of the cycle on the rate of increase in activity is quite high. The best result was obtained for a polynomial dependence (polynomial of degree 2) with R-Square (COD) = 0.84. In this case, the duration of the growth phase of the 25th cycle should be 57.8 months. For a linear dependence, we have the best result for the Pearson coefficient r = - 0.88. In this case, the duration of the growth phase of the 25th cycle should be 58.8 months. Based on the result obtained for the duration of the growth phase of the 25th cycle, an estimate of the duration of the 25th cycle was made based on the obtained dependence of the cycle duration on the duration of the activity increase phase. The best result for the polynomial dependence for the 25th cycle is 11.5 years. For a linear dependence, we have the best result for the Pearson coefficient r = 0.56. In this case, the duration of the 25th cycle should be 11.2 years.

Application of Machine Learning Methods for Geomagnetic Activity Forecasting

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The study of solar-terrestrial interactions and forecasting of geomagnetic activity is crucial for understanding and mitigating the effects of space weather on satellite systems, navigation, and communication technologies. In recent years, the significant increase in available observational and simulation data has necessitated the use of advanced data-driven methods, particularly Machine Learning (ML), to enhance the accuracy and reliability of predictions.

This research presents a comparative analysis of several cutting-edge ML models applied to the forecasting of geomagnetic indices: Dst, Kp, and AE. These indices serve as key indicators of geomagnetic storms and substorm activity. The models evaluated include RandomForest, XGBoost, LSTM, CNN+LSTM, RNN and Transformer-based architectures.

We investigate the models' performance in terms of prediction accuracy on validation datasets, training and inference efficiency, and data requirements. Our findings show that deep neural networks (particularly LSTM, CNN+LSTM, Transformer-based models) significantly outperform traditional algorithms due to their ability to extract and generalize complex temporal and nonlinear patterns in geomagnetic time series data.

The work is carried out in the framework of project No. 25BF051-04 "High-energy processes in plasma: acceleration of cosmic rays and their contribution to space weather" and The Royal Society International Exchanges Scheme 2021 IES\R1\211177 “Predicting natural hazards by driven ionospheric perturbations”.

"Solar" forces of spectral line oscillators

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The study of many physical quantities is carried out using spectral line contours. This applies to both laboratory and astrophysical studies, for example, when determining the content of various chemical elements. The intensities of spectral lines, in addition to the physical conditions of the environment in which they are formed, also depend on an important atomic parameter of a particular line - the oscillator power f. In practice, as a rule, the value of *Agf* is used - the product of the chemical content *A*, the statistical weight of the atomic level *g* and the oscillator power *f*. The most accurate data on the *gf* value are necessary for: building models of the interiors and atmospheres of stars; solving the cosmological problem - the origin of chemical elements in the Universe.

In some astronomical bodies, it is necessary to determine the content of heavy chemical elements, which are three orders of magnitude less than in the Sun. The task of searching for stars in which there are no metals at all is urgent. To find the answer to all these questions, we need the most accurate values of the chemical element content, and thus a sufficiently complete and accurate system of oscillator strengths of the corresponding spectral lines. At present, there is no such system of oscillator strengths that would satisfy these two requirements.

The results of studies of the solar spectrum have led us to the conclusion that the solar atmosphere has already been studied so well that it makes it possible to use it as a natural high-temperature environment for the purpose of determining the oscillator strengths of those spectral lines that are formed in it. This method of finding the *gf* values has the following advantages: most of the Fraunhofer lines in the solar spectrum are formed under *LTE* conditions, which makes it possible to use a relatively simple theory in calculations.

In the process of work, we had to conduct some preliminary studies: 1) to make sure that the model of micro-macroturbulence of thermal velocities describes the contours of the Fraunhofer lines quite accurately; 2) to conclude that in the solar atmosphere the attenuation constant $\gamma 6$ is close to the value described by the Unzold formula; 3) to make sure that the solar

model of Holweger-Muller practically "compensates" for deviations from local thermodynamic equilibrium.

We determined the oscillator strengths for 1958 lines of 49 chemical elements in the wavelength range 303-996 nm. For the lines of chemical elements that are represented in the solar spectrum in small quantities and which are significantly blended, we applied the method of spectrum synthesis. Whenever possible (where we were able to find the appropriate data), the ultrafine structure of spectral lines was taken into account. For most lines (1798) the oscillator strengths were found both in terms of equivalent width and central depth. We also give the effective heights of line formation in the center of the solar disk, equivalent widths and central intensities.

Molecular chaperone system as an essential component of protein life form on the example of plants

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In searching for life in the Universe and studying its nature, we currently have no other examples except protein life forms. The functional structure of proteins in the cell is controlled by molecular chaperones/heat shock proteins (HSP). In plants, HSPs are present in large quantities under normal (on Earth) growth conditions, accumulate in response to exposure to extreme factors (within the range of the organism's tolerance), as well as during seed development. The harsh conditions of the space environment include life-critical factors such as radiation exposure (ultraviolet (UV) and ionizing radiation), microgravity, temperature shifts, lack of water, etc. Dry seeds, due to their high resistance to extreme conditions and ionizing radiation, are considered as a candidate for a panspermia travel. Other stages of plant ontogenesis are vulnerable. In a series of terrestrial experiments with *Arabidopsis thaliana*, we demonstrated roles of chaperones/ HSPs at different developmental stages under different conditions.

The ability of HSP90 to buffer genetic changes from displaying in a phenotype was shown in Col and L*er* ecotypes after: (1) exposure of dry seeds to γ-irradiation (0.1-1 kGy, ^{60}Co); (2) exposure of imbibed seeds to UV-B (0.017-4.1 kJ/m^2). Treatment of irradiated seeds with geldanamycin

(GDA, an HSP90 inhibitor) resulted in increased variability in growth rate and morphological diversity of seedlings in a dose-dependent manner.

Upregulation of inducible HSP70 and HSP90 was determined in Col seedlings: (1) after γ-irradiation (1 kGy) of seeds; (2) under high temperature (45°C); (3) water shortage; and (4) simulated microgravity (clinorotation). Considering that HSPs are a self-regulating system, and using GDA, we confirmed the function of HSP90 in regulating their induction.

Furthermore, using loss-of-function mutants *Athsp90-1*, *Athsp90-4*, *Athsp70-5*, and *Athsp70-14*, the involvement of cytosolic HSP70 and HSP90 in the plastic response of seedlings to gravity stimulation and normal plant morphogenesis was demonstrated. Their specific role in canalization/stabilization of the plant phenotype formation and root gravitropic response was determined.

These results indicate that chaperones are an ancient protein control system that is of the utmost importance for protecting cells and maintaining normal ontogenesis, suggesting that they may be essential for all forms of protein life.

Memory span of solar cycle

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When predicting solar activity cycles within the framework of dynamo theory using solar observations, researchers in recent years have relied on similar in nature models of the turbulent αΩ-dynamo of the solar cycle with magnetic flux transport, but with a different emphasis on the nature of the magnetic flux transport mechanisms. The essence of the differences lies in the estimation of the relative contribution to the model of diffuse and meridional magnetic flux transport in the solar convective zone (SCZ). Some researchers are developing numerical models of αΩ-dynamos with low turbulent diffusion of the magnetic field ($\sim 10^8$ cm^2/s), in which the main mechanism for magnetic flux transport is meridional circulation (so-called advection). In this mode, which is commonly called the “dynamo model with dominant magnetic flux transfer due to advection” (AD-dynamo mode), the surface poloidal magnetic field of the current cycle (generated as

a result of the α-effect) is transferred first from the middle heliolatitudes to the poles, then down to the bottom of the solar convective zone (SCZ) in the tachocline region, and then is transferred in the equatorial direction to low heliolatitudes. However, alternative models introduce a regime with high turbulent diffusion of the magnetic field (~ 10^{13} cm^2/s), in which the surface poloidal field is transferred downwards to the tachocline mainly due to turbulent diffusion – this is the "dynamo model with dominant magnetic flux transfer due to turbulent diffusion" (DD-dynamo mode). As a result of theoretical studies, it was found that the main difference between solar activity forecasts based on models in the AD and DD modes lies in the different memory span of the solar cycle. In the work [Yeates A.R. et al.//Ap. J. 2008. V.673. P.544], based on simulations in which the source of the poloidal field varied stochastically in time, a study of the correlation between the polar magnetic flux at the minimum of cycle ***n*** and the amplitude (total spot area) of cycles ***n***, ***n* + 1**, ***n* + 2** and ***n* + 3** was conducted. It was found that in the DD mode, the polar magnetic flux at the minimum of the solar cycle ***n*** correlates only with the amplitude of the next cycle (***n* + 1**), while in the AD mode, the polar magnetic flux at the minimum of cycle ***n*** correlates with the amplitudes of cycles ***n***, ***n* + 1**, and ***n* + 2**.

The problem of solar cycle memory has been investigated from an observational point of view [Muñoz-Jaramillo A. et al. //Ap. J. Lett. 2013. V.767. L25]. Based on the processing of data on measurements of sunspot area and polar magnetic flux covering a time period of more than a century, only one significant correlation was found between the polar magnetic flux at the minimum of cycle ***n*** and the amplitude of the next cycle ***n* + 1**. This result indicates that the ***memory span of the solar cycle is limited to only one cycle***. In light of theoretical studies, ***this suggests that DD models are consistent with observations data***, while AD models are inconsistent with observations. Therefore, it is important to clarify which models may be more acceptable for the physical conditions in the depths of the Sun.

Our calculations, carried out within the framework of the mixing length theory (using physical parameters from the SCZ model by Stix [The Sun. 2002]), showed that the turbulent diffusion of the magnetic field of solar plasma reaches quite high values (~ $3 \cdot 10^{12}$-10^{13} cm^2/s) [Krivodubskij V.N. //Astron. Nachrichten. 2005. V.326, No 1. P. 61; Krivodubskij V.N. // Kinematic Phys. Celest. Bodies. 2012. V. 28, No 5. P. 232]. Therefore, it is clear that the Sun is dominated by a flux-transport dynamo with high turbulent magnetic diffusion (DD regime). Based on this, it can be assumed (taking into account the physical conditions in the solar layers) that only DD

models are able to explain the short-term memory span of one cycle ahead (inherent in solar cycles).

Ambiguity in the estimation of magnetic fields of solar flares and spots due to the dense overlapping of spectra of many elements

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The Vienna Atomic Line Database provides extensive information on atomic transitions. The VALD spectral line lists were significantly expanded during 2012-2016, and it is important to use the new data for solar spectroscopy. Zeeman spectrograms of active solar formations were studied. The problem of interpreting the zeeman splitting in the Fe1 5234.5 Å line, which is relevant for the case of superimposing 5 more spectral lines on it in the wing and core region, was investigated. The result will cast doubt on the presence of ultra-strong magnetic fields at sunspots and flares.

Social consequences of scientific errors

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Widespread media reports about geomagnetic storms from the so-called "Meteoagent" resource in most cases do not coincide with scientific forecasts from the NOAA Space Weather Prediction Center. For the population, the expectation of a worsening geomagnetic situation causes much more harm than actually strong geomagnetic storms.

Publications about a "cold" solar flare with a temperature of about 36,000 degrees allow the population to be intimidated not only by strong flares, but also by prominences. An even more dangerous consequence of the supposedly confirmed existence of “cold” solar flares is the patenting of a method for decomposing toxic, biologically hazardous, and radioactive waste into elementary particles when such temperatures are reached in ground-based laboratories.

Pseudoscientific ideas about "biological transmutation" give false hope that the transformation of Cs-137 and Sr-90 into stable elements can be carried out by living organisms.

The use of lasers to supposedly create new elements has led to the creation of pseudoscientific laboratories, which are spending considerable funds in conditions of economic hardship.

Adherence to scientific integrity is necessary not only for the development of science, but is also one of the conditions for economic stability.

Probing the sunspot magnetic field using direct spectro-polarimetric measurements in the lines of various chemical elements

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The most reliable data on magnetic fields in sunspots are obtained based on the study of the Zeeman effect in the lines of neutral iron Fe I with large Lande factors, within 2.5 - 3.0. Since sunspots are very heterogeneous formations, with an extremely fine (spatially indistinguishable) structure of the magnetic field and the distribution of thermodynamic parameters, it is of considerable interest to compare the measured magnetic fields in the lines of other chemical elements, in particular the lines of titanium and calcium. These lines are significantly enhanced in sunspots and more closely reflect the physical conditions in the coldest areas of sunspots, where particularly strong magnetic fields can exist. That is why the purpose of this work is to study the magnetic fields in the sunspot by the spectral lines of titanium, calcium and iron.

The spectral-polarization method of measuring magnetic fields was used to process observations made on the Echelle spectrograph of the horizontal solar telescope of the Astronomical Observatory of the Taras Shevchenko National University of Kyiv. The Zeeman spectrogram of the sunspot on July 17, 2023 was scanned using an Epson Perfection V 550 scanner and digitized taking into account the nonlinearity of the characteristic curves of both the photographic material and the scanner itself. Estimates of the

longitudinal and local magnetic fields in the studied spot were obtained based on the study of the splitting of the bisectors of the I ± V profiles of the Ti I 6554.238 and 6556.066 Å, Fe I 6569.224 Å and Ca I 6572.795 Å lines.

Since the above spectral lines have incomplete spectral splitting due to low Lande factors (from 1.08 to 1.5), estimates of only the longitudinal component of the magnetic field BLOS, and not the intensity modulus, were obtained from direct measurements. This parameter in some places of the spot significantly differs by the lines of different elements and has the highest values (up to 2400 G) by the Ti I 6556.066 Å line. The data for both titanium "shadow" lines correlate well with each other, but the Ti I 6556.066 Å line shows significantly higher fields everywhere than the other titanium line. It is interesting to note that the other "shadow" line, namely Ca I 6572.795 Å, shows the lowest measured fields, up to 1700 G. In the latter line, the bisectors of the I ± V profiles have a maximum splitting at a distance of about 0.32 Å from its center, which may indicate particularly strong local fields with an intensity of about 10.5 kG.

Comparison of direct measurements of the magnetic field with the calculated depths of the formation of spectral lines in the sunspot showed that the altitudinal gradient of the magnetic field reached quite large values, about 10 G/km, in absolute value. It was also found that in the altitude range from -369.8 to -291.4 km the altitudinal gradient of the magnetic field changed its sign. Such a case, as far as the authors know, has never been observed in spots. It is possible, however, that in this case not only the height of the formation of the lines plays a role, but also their different temperature sensitivity to changes in thermodynamic conditions at different depths in the spot.

Spectral manifestations of local magnetic field amplification at the chromospheric level of a solar flare

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Current estimates of local magnetic fields in solar flares vary greatly and are in the range of 10^2–10^5 G. This is partly due to the fact that solar flares are actually very different in their physical characteristics, but also to the fact

that different methods of measuring the magnetic field are not equivalent to each other, especially if the magnetic field is significantly inhomogeneous. The least studied based on direct methods are the magnetic fields in the solar chromosphere and corona. That is why the purpose of the presented work is new estimates of chromospheric magnetic fields in a solar flare based on the analysis of the characteristic features of the Zeeman effect in the Hα line and comparison of the corresponding results with those that follow from the study of the magnetic splitting of the photospheric line Fe I 6569.2 A.

The spectral-polarization method of measuring magnetic fields was used to process observations made with the Echelle spectrograph of the horizontal solar telescope of the Astronomical Observatory of the Taras Shevchenko National University of Kyiv. The Zeeman spectrogram of the solar flare of November 5, 2004 with a magnitude of M4.1/1B for the moment of 11:37 UT was scanned, and the blackening on the spectrogram was converted into intensity taking into account the characteristic curves of both the photographic material and the scanner itself. Estimates of the averaged and local magnetic fields in the solar flare region and in neighboring areas on the Sun were made on the basis of studying the splitting of the bisectors of the I ± V profiles of the above lines.

Significant signs of altitudinal inhomogeneity of the magnetic field were found in the height range "photosphere - chromosphere". This is indicated by the fact that the longitudinal component B_{LOS} of the magnetic field was significantly different in value for the specified spectral lines. In the solar flare region, the corresponding intensities were greater by the Hα line than by the Fe I line, while outside the flare, their inverse ratio was obtained. In addition, the bisectors of the I ± V profiles in the Hα line everywhere in the studied regions do not correspond to a homogeneous magnetic field: they are mostly not parallel to each other, and in the flare region they have a maximum splitting near the centers of the emission profiles. The non-parallelism of the bisectors in the Hα line indicates that the maximal magnetic fields at the chromospheric level were significantly stronger than 1.5 kG, and possibly reached the level of 10^4 G.

Magnetic field measurements on horizontal solar telescope of Astronomical observatory of Taras Shevchenko National University of Kyiv in 2024

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The horizontal solar telescope of the Astronomical Observatory of Taras Shevchenko National University of Kyiv (HST AO KNU) has been used for 50 years for spectral observations of solar activity and for photographic and visual measurements of solar magnetic fields. The telescope is equipped with an Echelle spectrograph; the main advantage of observations with such spectrograph is that a wide spectrum interval, from 3800 to 6600 Å, can be recorded simultaneously where many thousands of spectral lines can be observed. Another advantage is that I + V and I – V spectra are obtained simultaneously, on separate adjacent bands of the spectrograms. Spectral resolution is 50 mÅ in green region, and the spatial resolution, as rule, is about 1.5-2 Mm in morning time.

In 2024, the observation season lasted from March 26 to November 7. There were a total of 47 days of observations of sunspots on the entire disk of the Sun, of which 44 days were spent measuring the magnetic fields of the sunspot umbra. The observations were carried out by Vsevolod Lozitsky using FeI 5250.2 line, and processing of the visual magnetic field measurements was done by Natalia Lozitska. In general, magnetic fields of 114 spots were visually measured. 78 of the measured spots have a size of 30-60 arcsec. Based on the magnetic field of these sunspots, it was found that the index of the intensity modulus of large spots Bsp was 2680 G, which exceeds the value of last year and indicates that the Sun is approaching the maximum of the 11-year activity cycle.

The first exposure experiment with bacterial extracellular vesicles on the International Space Station

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In extraterrestrial environments, under anoxic conditions, radiation-induced changes in lipids could vary significantly compared to Earth-like conditions, with implications for the stability of the cell membrane. Membrane molecules like hopanoids are attractive for research due to their robustness and longevity, as well as their regulation of the cell membrane rigidity/fluidity. Hopanoids have drawn a strong interest from planetary and space biologists as a potential biosignature for life detection missions to other planets (Parnell et al., 2007). In the current sub-project in the BioSigN experiment (European Space Agency), we will use our previous findings - the presence of protein-coding genes associated with hopanoid biosynthesis in the *Komagataeibacter oboediens* genome, a non-pathogenic bacterium from a kombucha microbial community (KMC) (Santana de Carvalho et al., 2022). Hopanoid lipids might have crucial importance in tolerance to space- and Mars-like stress conditions simulated on the International Space Station (ISS) since KMC UV-irradiated samples displayed the highest read relative abundance of the protein-coding gene squalene-hopene cyclase (*shc*) (Góes-Neto et al., 2021). In this sub-project, to characterize the *K. oboediens* extracellular vesicles (EVs), the analysis of proteins and lipids (hopanoids) of the vesicle membrane, as well as other molecular cargo, will be performed for the selection of EVs with structural biosignatures. Samples of selected EVs will be isolated to be exposed in the ISS experiment. Ground-based tests simulating spaceflight and exposure conditions (in Cologne,

Germany), as well as a space exposure experiment on the ISS, will determine how bacterial EVs experience harsh flight and simulated Martian or icy moon conditions, and whether they retain their integrity and preserve their hopanoid biosignature.

Internal LOS Velocities of the Ernest Gurtovenko Solar Telescope Spectrograph

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The internal LOS (Light of Sight) velocities in the spectrograph are one of the key quality characteristics of the instrument. On the basis of long-term series of homogeneous measurements of the profiles of the 632.8 nm laser line, the parameters of the internal radial velocities of the Ernest Gurtovenko solar telescope spectrograph were determined.

Measurements were carried out in the 4th order of the spectrum by the SBIG-8300M camera with an entrance slit height of 11 mm. The duration of each series of measurements was ~100 seconds.

The accuracy of measurements of spectral shifts was not worse than 0.1 micron, which corresponds to ~2 m/sec for the studied spectrum region. Analysis of the measured shifts along the spectral line showed that the size of spatial disturbances in front of the receiver lies in a wide range starting from 100 microns.

Temporal and spatial fluctuations of the spectra were evaluated. It is shown that under optimal conditions it is possible to provide temporal and spatial tremors within the limits of up to 10 m/sec for the frequency range < 0.3 Hz and on scales > 3 arcsec.

However, there are two sources of error that can significantly degrade these values: 1) vibration of the rotating mechanism of the grating even in the absence of residual drift; 2) disturbance of the air in front of the receiver during the morning equalization of the temperature regime in the spectrograph pavilion.

Machine learning-based classification of plasma regions around particle acceleration events

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Magnetic reconnection plays a key role in plasma energization and particle acceleration in various regions of the Earth's magnetosphere, including the magnetotail and dayside magnetopause. In this study, we present a machine learning-based approach for automated classification of plasma regions surrounding reconnection-driven particle acceleration events.

We compare two neural network models: the first uses 3D ion energy distributions as input, while the second, more comprehensive model, ingests 12 plasma parameters, including magnetic field components, particle number density, bulk velocity, and both parallel and perpendicular temperatures. The models were trained and validated using data from the MMS mission.

We perform a comparative analysis of the models' classification accuracy and spatial consistency across reconnection regions. Both models successfully distinguish key plasma regimes such as magnetosheath, boundary layer, plasma sheet, and magnetospheric lobe. The 12-parameter model demonstrates improved generalization and robustness in complex transitional regions.

The work is carried out in the framework of project No. 25BF051-04 "High-energy processes in plasma: acceleration of cosmic rays and their contribution to space weather" and The Royal Society International Exchanges Scheme 2021 IES\R1\211177 "Predicting natural hazards by driven ionospheric perturbations".

Lower atmosphere dynamics of a powerful solar flare in the super active region NOAA 13664

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We present the first results of spectral study of the powerful X2.3 class flare which occurred in the super active region (AR) NOAA 13664. This AR was one of the largest and most active solar regions observed in the current 25th solar cycle. In terms of morphological characteristics and impact on the geomagnetic situation, AR 13664 was similar to the well-known Carrington area, which in September 1859 initiated the most powerful geomagnetic storm in all time of observations. AR 13664 produced many very strong solar flares and powerful coronal mass ejections, causing the most extreme G5 class geomagnetic storm in the last 20 years.

Spectrograms of one of the powerful flares of the X2.3 class that occurred in AR 13664 were recorded on May 9, 2024 with the Ernest Gurtovenko horizontal solar telescope of the Main Astronomical Observatory of NAS of Ukraine using the SBIG ST-8300M CCD camera. Three time series of spectra were recorded during the observations. One of them, which includes 20 two-dimensional spectra obtained during the main phase of the flare, was considered in this work.

To investigate the changes that occurred in the AR site studied atmosphere under the influence of the flare, we used a spectral region that contains the chromospheric Hα line and the Fraunhofer lines FeI, SiI, TiI. Profiles of these lines were obtained. It turned out that all the Hα emission line profiles in the spectra show absorption in the core of the line. They were broad, double-headed, had red asymmetry and expanded wings. The changes in the intensity of the Hα line emission over time show peaks at 35 s intervals, indicating a pulsed release of the flare energy due to successive and periodic magnetic reconnections. During the observations, the chromospheric matter moved downwards, its changes were oscillatory. It is noteworthy that changes in the brightness of the flare node occurred in antiphase with changes in the velocity of chromospheric matter. The difference in line-of-sight velocity in the upper layers of the flare and in the undisturbed region was 0.5-1.5 km/s, and in the middle and lower layers it was 1.8-3.2 km/s. The velocity of the downward flow increased when moving from the upper layers to the lower ones. This was probably a

consequence of the fact that the disturbance that arose in the upper layer of the solar atmosphere in the magnetic reconnection region spread to the lower layers. Under the influence of heat flows and high-energy electrons, the presence of which is indicated by the shape of the obtained Hα line profiles, condensation formed in the chromosphere and moved downwards.

As to photospheric lines, the largest changes in the intensity during flare occurred in the FeI and SiI lines, and they were insignificant in the TiI line. At the photosphere level, matter descended, its changes were oscillatory, and the velocity decreased with time. However, the peaks of the velocity increase in the photosphere were observed ~10 s later than in the chromosphere. The excess of line-of-sight velocity relative to its value for the undisturbed photosphere ranged from 0.37 to 0.05 km/s.

Our study shows that the features of changes in the flare site atmosphere were likely associated with the passage of chromospheric condensation and waves that were formed during the pulsed release of energy as a result of magnetic reconnection in the upper layers of the AR atmosphere.

Current density determination in the near-Earth environment: multispacecraft and particle approaches

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Determination of current density using the multispacecraft approach provides a lot of information about magnetospheric current systems and structures. Four-spacecraft tetrahedron configuration allows to use magnetic field measurements for estimation the electric current density relaying on Amper's law. This approach is suitable for magnetospheric regions, which has high-conductivity plasma.

Magnetic reconnection events in the tail of Earth magnetosphere observed by MMS mission are considered. Magnetic reconnection events were chosen for two reasons: 1) the need to find the current density for estimating electromagnetic field energy dissipation and particle

acceleration, 2) MMS particle data have higher time resolution for such events, since the mission science team confirms the transmission of such data to ground segment for valuable events. We have performed comparative estimates between multispacecraft and direct current determination from particle moments. Particle measurements are characterized by a large amount of noise compared to the multispacecraft approach. However, only particle measurements can be an estimate of the current density in cases where the tetrahedron quality factor for the satellite constellation is low, that is, when their configuration differs maximally from a regular tetrahedron.

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Prediction of amplitude of Solar Cycle 26

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Solar activity affects on space weather and many space-borne and ground-based high-technological systems. The knowing of the solar activity level in advance is important for modern humans' life.

We found a significant positive correlation between the amplitudes of the odd solar cycle and the next even cycle (the correlation coefficient was equal to 0.57 when the pair of cycles 7-8 was not taken into account, the regression equation was $Y = 61.8 + 0.5*X$). This allows us to use the amplitude of the current Solar Cycle 25, the maximum of which according to the smoothed monthly sunspot numbers was observed 160.8 in October 2024, to predict the maximum of the next Solar Cycle 26. It was obtained that the predicted amplitude of Solar Cycle 26 is 142.2 ± 52.7, i.e. Solar Cycle 26 will be higher than Solar Cycle 24 and lower than Solar Cycle 25.

Determination of the Horizontal Velocity Field in the Solar Atmosphere: Method Validation Using a 3D MHD Model

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The report presents testing of a diagnostic method for reconstructing the horizontal velocity field in the solar atmosphere at granular and subgranular spatio-temporal scales, originally proposed by M. I. Stodilka. It is based on the use of semi-empirical models of the solar atmosphere obtained through the solution of the inverse radiative transfer problem, in combination with the hydrodynamic equations to compute the horizontal velocity components. The application of this method requires solving a large system of linear equations using an iterative approach. The matrix of this system is sparse, which allows for efficient memory usage and accelerated matrix multiplication during the iterative solution procedure. A new computer code was developed to implement this approach.

The method was tested using a snapshot from a series of publicly available magnetohydrodynamic simulations of the solar atmosphere produced with the BIFROST code. The horizontal velocity field was calculated for a subregion of the simulation domain at various atmospheric heights. The comparison showed good agreement between the reconstructed velocity fields and the original MHD model data.

Effects of the manifestation of the solar eclipse according to the data of ionospheric scintillation by radiation from powerful radio sources and cosmic background on the RT "URAN-4" RI NASU and research prospects

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The solar eclipse of November 3, 2013 is being considered. Observations of the cosmic background low-frequency radio emission and scintillations of

radio sources showed an increase in the intensity of ionospheric scintillations and the cosmic background intensity on the day of the solar eclipse.

The URAN-4 low-frequency radio telescope (frequency range 10-30 MHz) is located on the territory of the Odessa Regional Magnetic Anomaly (ORMA). This provides a unique opportunity to study the features and properties of ionospheric response to magnetic and ionospheric storms and solar eclipse by recording ionospheric scintillations of powerful cosmic radio sources, whose radio emission passes through the layer of ionospheric plasma. The wavelet analysis method was used to analyze datasets, on the basis of which the main periods of scintillations of radio sources and fluctuations in background radio emission were identified. It is shown that ionospheric disturbances and cosmic background emission on decameter range caused by eclipse, significantly change the shape of ionospheric scintillations spectrograms for different radio sources, and the minimal scintillation “periods” observed on URAN-4, are reduced to 10-15 seconds on frequencies 20 and 25 MHz. Despite the fact that the solar eclipse of November 3, 2013 was invisible in Ukraine, and the closest area of partial eclipse was in Turkey, in comparison with control days before and after the eclipse, increase intensity of ionospheric scintillations of sources 3C 123, 3C 144, Cas-A was clearly noticeable, as well as increase intensity of cosmic radio noise and appearance of observable fluctuations, probably caused by wave activity of the ionosphere.

During the solar eclipse on March 29, 2025, comprehensive observations of the effects of its manifestation in the ionosphere were carried out using the radio telescopes of the URAN system of the RI NASU, the LOFAR radio telescope of the Ventspils University of Applied Sciences in Latvia, the Sodankyla observatory with radio telescope KAIRA (Finland) and a network of magnetometers along the "Struve Geodetic Arc" from Finland to Ukraine.

Specropolarimetric diagnostics of the solar coronal forbidden lines using P-CORONA code

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The scientific goal of the talk is to present the current state-of-the-art of coronal spectroplarimetry, based on using coronagraphically observed forbidden optical and near-infrared lines. Among them are the key polarized spectral lines of highly ionized atoms like Fe XIV λ5303, Fe XI λ7892, Fe XIII λ10746, Fe XIII λ10798, Si X λ14301, and Si IX λ39343. They enable a range of coronal plasma diagnostics for the magnetic field direction via linear polarization generated by anisotropic photoexcitation and the longitudinal magnetic field amplitude via Zeeman induced circular polarization.

Here, we present results of calculations of the intensity and polarization of the above lines in three-dimensional (3D) coronal models, using a novel forward-modelling code called P-CORONA. The code accounts for various physical mechanisms: scattering of anisotropic radiation, collisions with electrons and protons, the impact of magnetic field through the Hanle and Zeeman effects, and Doppler dimming and brightening. We demonstrate the capabilities of P-CORONA for two sets of models: MURaM simulations that extend into coronal heights and large-scale Predictive Science models.

The impact of solar activity on the Earth

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The Sun is the main source of energy and an important factor in the existence of the Earth's biosphere and technosphere. It provides light and supports life processes. The impact of space weather on the Earth and the Solar System is

becoming increasingly important during the preparation of manned space flights to the Moon and Martian missions. Analyzing materials of long-term homogeneous series of observations of the Sun and seismic, tectonic activity, changes in the hydrosphere, and the temperature of the Earth's surface (global and regional), we study the mechanisms of functioning of individual parts of the Sun-Earth system. A deeper understanding of the relationships between the Sun, humans, society, and nature will allow us to develop an idea of the system of solar-earth relations in general.

Available information on the eruptions of all known volcanoes in chronological order from 1750 to the present allowed us to analyze volcanic eruptions as a planetary process and to study the connections of this process with solar activity.

Oceans, seas, rivers, glaciers and snow cover (the totality of all water bodies - the hydrosphere) occupy more than 71% of the Earth's surface and are a very important climatic element. The hydrosphere represents a wide field for studying solar-terrestrial relations. We analyzed the connections of solar activity with the level of the world ocean and the area of the Arctic and Antarctic glaciers. The prolonged warming of surface waters in the central and eastern parts of the Pacific Ocean and the set of processes accompanying it is called El Niño/Southern Oscillation (ENSO) and is described by a special Southern Oscillation index. We analyzed the connection between the Southern Oscillation index and solar activity.

Continuous observations of the temperature of the surface layers of the air have been conducted at individual meteorological stations since the middle of the 19th century. We analyzed the course of the temperature index for individual regions, as well as the relationship between global Earth temperature and solar activity.

The existence of an 11-year (Wolf cycle) and/or a 22-year (magnetic solar) cycle was revealed for most of the analyzed Earth parameters.

Auroras as manifestations of solar activity

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Changes in the power of solar radiation significantly affect space climate and space weather. Usually, to study long-term variations and trends in solar activity (SA), the Wolf number (SN) - the number of sunspots - is used. The

number of groups of spots (GSN) and total solar radiation (TSI) are also used as indices. SN has been known quite accurately since 1848, when Wolf began his observations. GSN reconstruction from archival data has been carried out since 1610, when observations of the Sun using telescopes began. For longer periods of time (tens of thousands of years), data on radiocarbon in tree rings, cosmogenic isotopes (14C and 10Be), and the content of nitrates in polar ice are used to reconstruct SA. But the accuracy of such data both in the field of dating and in the field of reproducing the amount of solar radiation is insignificant. Therefore, for the reconstruction of the solar eclipse on a scale of about two thousand years, data on auroras are often used, records of which are found in historical documents since the 10th century BC. The number of auroras can be a measure of the numerical characteristics of the solar eclipse and its variations, since the course of the auroras reflects the course of solar activity.

Based on 37 separate catalogs, we have developed a consolidated series of auroras for 1000-1900 years, which includes 23,622 unique phenomena. In addition to the 11-year period, periods of 51, ~100 and ~200 years were distinguished in these data using the wavelet analysis method. Based on the comparison of the series of auroras and solar reconstructions, it is possible to assess the accuracy of the reproduction of solar activity in different years.

About life in "dry rivers" of Mars

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The presence of many long, winding valleys that resemble dried-up riverbeds on Earth should indicate that once upon a time there were conditions on the surface of Mars that could have supported liquid water. The main water reserves are now concentrated in the northern polar cap. Water reserves in the atmosphere are insignificant. Currently, water in various states is located under the surface of the planet. Areas under the surface at different depths can be a kind of oases for various biological activities. Therefore, these undersurface regions as well as areas of Mars covered with clay, can be a promising place to search for traces of life. Since the temperature at the base of the polar cap is estimated at 205 K, it is believed that water can remain liquid there due to the antifreeze effect of magnesium and calcium perchlorates.

The Mars rover Spirit was sent to the Gusev crater with a diameter of 180 km located near the equator. An ancient river flowed into this crater, so it could have been a lake in the past. The Mars rover Opportunity landed in the Eagle crater, located near the equator on the opposite side of Mars from the Gusev crater. There an increased concentration of hematite was found which on Earth is formed only in an aqueous environment. The main mission of the Mars rover Perseverance is to search for the presence of modern signs of bacterial life on Mars, or its existence in the past. For this purpose, it was sent to the Ezero crater. Its sedimentary rocks could well have initiated the development of certain life forms. Spectral observations by the Mars rover Perseverance showed that organic molecules were found in some of the rocks and fossilized mud. Organic molecules are the basis of all life on the planet.

There is many evidence that Mars had a powerful hydrosphere between 3.5 and 2.5 billion years ago. Measurements by the Curiosity rover have allowed to estimate the amount of water Mars has lost. The data suggest that Mars was not just covered in water in the past but could have retained it in liquid form for hundreds of millions of years. Studies of the ratio of deuterium to hydrogen in its atmosphere suggest that greenhouse gases could have retained water in liquid form and prevented it from freezing. Greenhouse gases were quite capable of warming Mars enough to maintain a stable climate for millions of years. This allowed for the conditions for chemical evolution, a stage that precedes the emergence of life.

Chromospheric Spectra of Small-scale Dynamic Features observed On and Off Solar Disk

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High-resolution chromospheric observations with the Goode Solar Telescope (GST) reveal new insights into the dynamics of small-scale solar features, particularly rapid blue- and red-shifted excursions (RBEs and RREs). Case studies show that some RBEs coincide with localized

brightenings (~0.2 Mm) in the lower chromosphere, often near granules and persistent photospheric bright points, suggesting a link to small-scale energy release processes. The co-occurrence of strong blue shifts and elevated temperatures (>10^4 K) supports scenarios involving rapid plasma heating and upward motion, consistent with type II spicule behavior.

Spectral analysis across the solar limb shows reduced far-wing intensity above the disk and persistent blue-wing dominance, indicative of changing optical depth and stable velocity fields. Off-limb Hα profiles exhibit asymmetric, multi-peaked structures, suggesting complex internal motions—possibly Alfvén waves, bidirectional flows, or torsional dynamics—enhanced by radiative transfer effects. Line-of-sight integration complicates interpretation, particularly off-limb.

Both on-disk and off-limb data consistently show prevalent blue shifts, with red shifts localized near network regions, implying widespread upflows and more confined return flows. These findings reinforce the connection between chromospheric dynamics and small-scale magnetic field evolution, including flux emergence and reconnection.

Solar flares as electric circuits detected in multi-wavelength observations and sunquakes

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Solar flares are magnificent events evolving from the corona to the photosphere and beneath while demonstrating a significant increase of emission in hard X-rays, gamma-rays, soft X-rays, EUV, UV and optical emission often accompanied by the occurrence of surface ripples (sunquakes) emanating from the locations of flares. In this talk I will describe how solar flares are initiated by the interaction of magnetic flux tubes and igniting magnetic reconnection, which, in turn, initiates acceleration of the ambient plasma particles (electrons and ions) to sub-relativistic velocities. I will demonstrate accelerated particle energy and pitch angle distributions derived from 3D test particle and Particle-in-Cell (PIC) simulations. These energetic electrons will be shown using time-dependent Fokker-Planck approach to

precipitate from the corona downwards into flaring atmospheres in Coulomb collisions and Ohmic scattering in the electric field induced by precipitating electrons leading to return current electrons travelling back to the corona, thus forming an electric circuit supporting the solar flare progress. The precipitation of energetic electrons will be explored in magnetic loops with different convergence. It will be also shown that this electric circuit of solar flares and the sub-relativistic (1/3c) speed of precipitating electrons secures resolution of particle number problem for electrons required to account for HXR bremsstrahlung emission observed in flares. By considering particle wave interaction we demonstrate formation of zebra-patterns in third type of MW bursts. Heating caused by precipitating particles is shown to result in hydrodynamic responses of the ambient plasma, explosive evaporation of the ambient chromosphere into the corona and a formation of super sound hydrodynamic shocks travelling downwards the photosphere and beneath. These the shocks will be shown to initiate generation of a seismic response of the solar interior beneath the flaring atmosphere resulting in generation of acoustic waves, or sunquakes, on frequencies above the acoustic cut-off frequency. A few examples of the detected seismic waves with the first and second bounces will be presented and compared with observations.

Modern grand solar minimum and its impact on the terrestrial environment

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In this talk we will revisit our prediction by Zharkova et al., 2015 https://www.nature.com/articles/srep15689 of the grand solar minimum using the collar background magnetic field and deriving its eigen vectors using the Principle Component Analysis, compare it with the whole dataset (25 cycles) of sunspot numbers, derive spectral characteristics of both dataset and demonstrate that modern GSM is already in progress with the most recent updates from the terrestrial weather, ice coverage and other terrestrial features. We also provide the reasonable prediction of the expected impacts of the GSM on the whole Globe using the evaluations by Shindell et al, 2001,

Science https://earthobservatory.nasa.gov/images/7122/chilly-temperatures-during-the-maunder-minimum and propose possible ways to reduce the sever impact of the cold patches on the population.

Solar-like five-minute oscillations in variable stars

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We report the results of observations of small-scale variability in the Balmer lines eps Cep, zeta Ori A, 109 Vir. The spectral observations were made with a low-resolution spectrograph ($R \simeq 600$) installed at the Main Astronomical Observatory, Ukraine. The spectra were obtained with a temporal resolution of a few seconds.

It was found that variations of the hydrogen lines Hβ, Hγ, Hδ, and Hϵ are observed in all stars. They have discrete frequencies of about 3 mHz, similar to the five-minute oscillations excited by p-modes in the Sun. The characteristic times of the observed oscillations range from 400 to 1600 s. The horizontal scale for the oscillations ranges from 125 to 140 Mm. The radial velocity of the oscillations ranges from 180 km/s to 450 km/s.

ATMOSPHERE AND IONOSPHERE RESEARCH

Global features of ionospheric storm September 11–21, 2024

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Solar storms, accompanied by coronal mass ejections, flashes of electromagnetic and corpuscular radiation, and the generation of high-speed solar wind flows, reaching the Earth, cause geospace storms. Geospace storms are synergistically interacting ionospheric, magnetospheric, atmospheric storms, and storms in geophysical fields. Geospace storms caused by solar activity significantly affect ionospheric weather, which, in turn, determines the efficiency of ground-based and space-based systems. One of the most powerful was the storm that occurred on September 11–21, 2024. The purpose of the report is to describe the global features of ionospheric storms in the period from September 11 to 21, 2024. During the period from September 8 to 14, the active solar regions NOAA 13814 and 13825 caused a series of powerful flares (classes C, M, X), in particular the X4.54 flare on September 14. On the night of September 17, the K_p-index increased from 4 to 7, and during the day it fluctuated within the range from 5 to 7. During the period from September 12 to 17, a series of less intense magnetic storms were observed, the K_p-index of which varied from 4+ to 7-. From September 10 to 11, 2024, the D_{st}-index fluctuated near ~0 nT. Between 23:00 on September 10 and 04:00 on September 11, it suddenly increased from 7 to 38 nT, which corresponds to the initial phase of the magnetic storm. From 04:00 to 14:00, a rapid decrease in the D_{st}-index was observed to a minimum value of –121 nT, which indicates the main phase of the storm. Starting from 14:00, the recovery phase began: the D_{st}-index, fluctuating, increased from a minimum of –121 nT to –25 nT. On the night of September 16-17, 2024, a second storm began. Around 23:00, the D_{st}-index increased from –25 nT to –11 nT. After 23:00, the D_{st}-index began to decrease and reached a minimum value of –121 nT at 08:00. After that, fluctuating, it gradually increased to ~0 nT. During the second storm (night of September 16-17), strong ionospheric disturbances were observed: the disappearance of the F2 layer and the appearance of reflections from the F1 layer (state G), blackouts lasting up to 120 hours. In the Eastern Hemisphere, on September 11, daytime f_oF2 values fluctuated between 9.2–12.4 MHz, nighttime values varied within 5–6.4 MHz. On September 12, a decrease in f_oF2 was observed in the north, and an increase was recorded in

the south, indicating mixed types of storms (positive and negative). On September 17, f_oF2 values decreased at most stations, negative storms prevailed, especially at night. In the Western Hemisphere, the situation was similar: on September 12, there was an increase in f_oF2 during the day and a decrease at night; on September 17, there was a general decrease in frequency, except for the CAJ2M station in the Southern Hemisphere, where a positive storm was recorded. In general, the storms were more intense at night. The duration of the blackouts varied from 10 to 25 h, and at CAJ2M — up to 120 h.

Global features of the November 4–7, 2023 multi-stage geomagnetic storm

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The paper studies the features of the manifestations of the unique multi-stage geomagnetic storm on November 4–7, 2023. To analyze the temporal variations in the geomagnetic field components, the measurement data from the international INTERMAGNET network stations were utilized. Preference was given to stations that were grouped around a certain meridian in the eastern and western hemispheres. Temporal variations in the levels of the X-, Y- and Z-components of the geomagnetic field from November 2 to 8, 2023 were analyzed. To obtain variations in the components, the average value of each component level for a given day was first calculated and then subtracted from the original time series. Next, the level of variations on November 4–7, 2023 was compared with the level of variations on the reference days (November 2, 3 and 8, 2023).

On November 4, 2023, at the high-latitude stations THL and AIA in the western hemisphere, the geomagnetic field variation ranges were 130 nT, 100 nT, 50 nT and 50 nT, 100 nT, 60 nT for the X-, Y- and Z-components, respectively. For the first magnetic storm on November 5, 2023, the ranges of variations in the X-, Y- and Z-components at the same stations did not exceed 130 nT, 375 nT, 100 nT and 125 nT, 100 nT, 100 nT, respectively. During the second and most intense magnetic storm on November 5, 2023, the ranges of variations in the X-, Y-, Z-components for the THL station reached 530 nT, 450 nT and 425 nT, and for the AIA station they were 160 nT, 150 nT and 200 nT.

On November 6, 2023, the ranges of variations in the X-, Y- and Z-components at the THL station reached 270 nT, 275 nT and 100 nT, while for the AIA station they did not exceed 50 nT, 60 nT and 75 nT, respectively. On November 7, 2023, for the THL and AIA stations, the ranges of variations in the X-, Y- and Z-components were within 130 nT, 150 nT, 125 nT and 40 nT, 30 nT and 50 nT, respectively.

For the southern hemisphere on November 4, 2023, at the high-latitude station HRN, the ranges of variations in the X-, Y- and Z-components were about 160 nT, 120 nT, and 120 nT, respectively. At the mid-latitude station MCQ, the ranges were about 120 nT, 100 nT, and 120 nT. For the first magnetic storm on November 5, 2023, at the HRN station, the ranges of variations in the X-, Y- and Z-components did not exceed 240 nT, 200 nT and 180 nT, respectively, for MCQ station, the ranges of variations were close to 450 nT, 200 nT and 400 nT. During the second and most intense magnetic storm on November 5, 2023, at the high-latitude HRN station, the ranges reached 480 nT, 600 nT and 330 nT for the X-, Y- and Z-components. For the mid-latitude MCQ station they were about 1100 nT, 800 nT and 900 nT, respectively. On November 6, 2023, the ranges of variations at the HRN station were close to 120 nT, 80 nT and 360 nT, while at the MCQ station the ranges were 500 nT, 100 nT and 200 nT. On November 7, 2023, at the HRN station, the ranges reached 600 nT, 300 nT, and 360 nT. At the MCQ station, the they were larger: 250 nT, 100 nT, and 100 nT.

From November 4 to 7, 2023, five magnetic storms of varying intensity were observed, with the second storm on November 5 being the strongest. The first four storms were preceded by bursts in the solar wind parameters. The solar wind structures with sharply increased parameters (shells), were the causes of the multi-step nature of the storm [1, 2]. The uniqueness of the magnetic storm of November 4–7, 2023 lies in its five-step nature, i.e., it consisted of five storms of varying intensity.

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Ionospheric response during strong geomagnetic storm on 10–11 April 2022

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The study of the effects and features of ionospheric storms at different phases of solar activity is an important and topical issue. Since the main background conditions are very different, the magnetosphere-ionosphere-atmosphere system reacts differently to geomagnetic storms at different phases of the solar activity cycle.

The purpose of the work is to study the response of the F2 layer of the ionosphere over Ukraine to a strong geomagnetic storm on April 10, 2022. The work presents the results of experimental studies on April 6–12, 2022, conducted using a digital ionosonde of the ionospheric observatory of the Institute of Ionosphere (Kharkiv).

The strong geomagnetic storm on April 10, 2022, was caused by a series of consecutive coronal mass ejections, starting on April 3, 2022. On April 10, the auroral activity index AE increased rapidly after 03:00 UT and reached a value of ~1700 nT at around 05:00. At that time, the index $K_{p\max} = 7–$.

Starting from April 9, 2022, when the relative deviation of the critical frequency δf_oF2 exceeded 20%, a series of negative ionospheric disturbances was observed over Kharkiv. The maximum changes in the peak density of the F2 layer (N_mF2) were observed on April 10 after the end of the main phase of the magnetic storm, namely at 19:45 UT: when δf_oF2 was –28.7%, N_mF2 decreased by a factor of 2 (from $3.2 \cdot 10^{11}$ to $1.6 \cdot 10^{11}$ m^{-3}). The decrease in N_mF2 was accompanied by a decrease in the ionospheric F2 peak height (h_mF2) by 30–45 km.

On April 11, 2022, the changes in NmF2 were even stronger: at 10:45 UT δfoF2 was –38.4%, N_mF2 decreased by a factor of 2.6 (from $10.8 \cdot 10^{11}$ to $4.1 \cdot 10^{11}$ m^{-3}). The decrease in the F2 peak electron density was accompanied by a decrease in h_mF2 by 40–50 km.

Long-term variability of aerosol properties over Kyiv from AERONET observations (2008–2024)

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This study presents a comprehensive analysis of aerosol optical and microphysical properties over Kyiv, Ukraine, using 15 years (2008–2024) of AERONET data. Seasonal and long-term variations in aerosol optical depth (AOD), Ångström exponent (AE), single scattering albedo (SSA), refractive index, and particle size distribution are investigated to characterize aerosol types and their temporal evolution. The results reveal pronounced seasonal patterns, with higher concentrations and larger particle sizes in winter and spring, and a shift towards smaller particles in summer and autumn. AOD showed a general declining trend over the study period, with notable fluctuations. AE exhibited a significant decrease in recent years, indicating a shift towards larger aerosol particles. High SSA values and stable Refractive Index suggest a predominance of scattering aerosols with consistent optical properties throughout the year. Seasonal variations in size distribution reflect the changing influence of various aerosol sources and atmospheric processes throughout the year. These findings contribute to the understanding of regional aerosol dynamics, with implications for climate modeling, satellite validation, and air quality management in Eastern Europe.

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Main characteristics of Antarctic total ozone data

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In the Antarctica, ground-based total ozone measurements have been carried out from the 1950s. Regular satellite measurements started from the end of 1978, creating quasi-global data. Multi-Sensor Reanalysis-2 is currently available from 1960, but it has large uncertainties for the first two decades due to low number of the observational stations in this period. A maximal variability is observed during southern spring months (September–November) with change of a seasonal maximum to a sharp minimum during the 1980s. Later, the ozone hole stabilized with the lowest total ozone levels 100–150 DU in its inner part. The maximal ozone hole area reaches 30 million km^2 at its peak size in separate springs.

Our analysis demonstrates the ozone hole development during the 1980s – early 1990s with a strong negative trend in total ozone. The modern yearly variations show zonal asymmetry with a more significant seasonal minimum in the highest southern latitudes and West Antarctica. The variations in the East Antarctica are closer to the typical ozone cycle in the middle latitudes. Respectively, the long-term changes in total ozone are also more noticeable in the West Antarctica. Quality of their polynomial approximation is analyzed as well.

Differences between the ground-based, satellite and reanalysis data are studied. It is worth noting that ground-based and satellite observations in the ultraviolet range are not carried out under the polar night conditions. Larger values of the differences are typically observed during several weeks before and after the winter gap. Some attempts of the observations by the full Moon light were done at the separate stations including Faraday/Vernadsky. These data demonstrate high dispersion and seem to be considered as partially unreliable. Large deviations are also found near the edge of the ozone hole where the high total ozone gradient typically exists. Respectively, this kind of significant differences is caused by unusual ozone distribution and fast movement of the ozone hole edge. In particular, similar situations are noticed for the Vernadsky station. In the summer and autumn

months, ozone is distributed more uniformly, and distinctions between different data are lesser.

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Stratospheric warmings in the Antarctica and their influence on the ozone distribution

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Dynamical processes in the Antarctic stratosphere are less intensive in comparison with the Arctic region. In particular, since the beginning of systematical research in the 1950s, a unique major stratospheric warming was observed. This event happened in the late September 2002 and caused splitting of the stratospheric polar vortex with increase in total ozone values. Nonetheless, two other large stratospheric warmings were noticed in Septembers of 1988 and 2019, also leading to the higher ozone levels in comparison with the neighboring years.

At this, the Antarctic stratosphere is permanently influenced by planetary waves disturbing the stratospheric polar vortex. Consequently, the Antarctic stratospheric warmings are not limited by the three mentioned events, and minor warmings can be also identified. We have determined minor warming phenomena, considering temperature and zonal wind distributions from MERRA-2 data. The average 60–90°S temperature and zonal wind at 60°S were analyzed searching positive and negative anomalies respectively. The obtained results show similar values of the anomalies for 2002 and 2019, and the rest of these events had lesser deviations from the climatological values.

Total ozone dependence on the three large stratospheric warmings (1988, 2002, and 2019) is studied with the use of the MSR-2 reanalysis. It is demonstrated that the ozone response is zonally asymmetrical. It is more

evident in the East Antarctica with positive deviations by tens Dobson Units during several weeks before the peak date of a warming. These preconditions show that the stratospheric warmings are not fully "sudden", as they are usually named. In the West Antarctica, total ozone rise is observed approximately one week after the warming event. The method of superposed epochs was used to determine typical features of these phenomena. We have also studied minor stratospheric warmings that have a weaker influence on total ozone, but are more numerous and, as a result, more appropriate for statistical analysis.

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Fractal Analysis of the Infrasound Signal Generated by the Tonga Volcano on January 15, 2022

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According to the non-linear and the system paradigms, many processes generated in the geospace, as in an open, non-linear, dynamical system, under influence of a powerful source of energy release are appeared to be short-time, ultra-wideband, non-linear and fractal. This fact can be successfully explained by existence of very complex and manifold interactions which usually observed between different subsystems in the geospace. Being the non-stationary powerful sources of energy release, the explosions and the eruptions of the volcanos are able to create many different complex processes in the geospace, which could have valuable and significant fractal properties. Therefore, the investigations of such properties seem to be actual.

The purpose of this work is to research the fractal properties of the infrasound signal registered during the powerful Tonga volcano eruption took place on January 15, 2022.

Due to existence of the allowed volume limitations, in bounds of the present work, to describe the fractal characteristics of the signal investigated, only mono-fractal analysis methods based on the rescaled range analysis (RRA) were applied.

As it could be waited, the signal was appeared to non-fractal in whole that is at all existing time scales simultaneously. Nevertheless, it can be considered

as mono-fractal one at some limited time scale intervals. Such situation is appeared to be not unique and not new at all. As a similar example, the well-known fractal properties of the sunspot number time series can be considered. The infrasound signal registration obtained during the Tonga volcano eruption took place on January 15, 2022 consists 1857140 samples, the sampling frequency is equal 40 Hz, the signal time duration is near 12.9 hour. Basing on the RRA as one of the most famous mono-fractal analysis methods, the limited time scale intervals, where the signal investigated has the mono-fractal properties, were found. The corresponding values of the Hurst index H and of the Hurst fractal dimension D were estimated. Using the window function in time domain, the time variations of these numerical parameters ($H(t)$ and $D(t)$) were obtained.

Grounding on the signal look in time domain, it was divided on seven parts, which seems have quietly different fractal properties. The fractal characteristics were estimated as for whole signal, as for each part separately. Despite the absents of the fractal properties for the whole signal analyzed, in was found that it can be considered as mono-fractal one, first, in the period range $T \approx 8-200$ s with $H = 0.314 \pm 0.003$ and $D = 1.686 \pm 0.003$, second, in the period range $T \approx 3000-14500$ s with $H = 0.337 \pm 0.001$ and $D = 1.663 \pm 0.001$, third, in the period range $T \approx 20300-46500$ s with $H = 0.401 \pm 0.001$ and $D = 1.599 \pm 0.001$. Adding the signal part number as the lower right index to the designations 'H' and 'D', we can write the same results obtained for each of seven signal parts in all period range as following; $H_1 = 0.303 \pm 0.001$ and $D_1 = 1.697 \pm 0.001$, $H_2 = 0.249 \pm 0.001$ and $D_2 = 1.751 \pm 0.001$, $H_3 = 0.933 \pm 0.002$ and $D_3 = 1.067 \pm 0.002$, $H_4 = 0.381 \pm 0.001$ and $D_4 = 1.619 \pm 0.001$, $H_5 = 0.275 \pm 0.001$ and $D_5 = 1.725 \pm 0.001$, $H_6 = 0.336 \pm 0.001$ and $D_6 = 1.664 \pm 0.001$, $H_7 = 0.302 \pm 0.001$ and $D_7 = 1.698 \pm 0.001$. As it can be seen, in most cases, the signal parts are appeared to be anti-persistent ($H < 0.5$). Being a powerful ultra-wideband process, the only third part is obtained to be persistent ($H > 0.5$). For each signal part and each period range described above, the H and D values were separately estimated too.

Response of the Total Electron Content in the Ionosphere to Powerful Solar Flares

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The ionosphere is a key component of near-Earth space that plays a crucial role in the interaction between solar activity and the Earth's atmosphere. It responds sensitively to variations in solar radiation, particularly during flares accompanied by significant energy emissions in the X-ray and ultraviolet ranges. These impulsive events cause additional ionization in the upper layers of the atmosphere, leading to changes in electron density and the total electron content (TEC).

In May 2024, the Sun exhibited high activity: during the period from May 8 to May 14, a series of M- and X-class flares was recorded. The most powerful of them was the X8.79 flare, which occurred on May 14 at 16:51 UTC and lasted 960 seconds. According to estimates, its power near Earth reached approximately 111 GW, and the total energy amounted to 53 TJ. Such events are accompanied by a sharp increase in ionization levels in the ionosphere, particularly in the sunlit sector, resulting in significant TEC variations on a global scale.

The purpose of this study is to investigate the response of TEC to powerful solar flares through the analysis of GNSS data. This approach allows for the assessment of real-time changes in ionospheric electron density and the identification of the impact of short-lived but intense pulses of solar radiation on near-Earth space.

To study the TEC dynamics, data from global navigation satellite systems (GNSS) were used, collected from the BOGT, PALM, POVE, RDSD, SANT, SCH2, and THU2 ground stations, with signal analysis from satellites G05, G06, G13, G14, G17, and G20. Depending on latitude and longitude, the baseline TEC values N_{V0} ranged from 30 to 90 TECU, with disturbance magnitudes from approximately ~1% to 3–5%. The observational results are in good agreement with model calculations, which yielded $N_V/N_{V0} - 1 \approx 1 - 5\%$.

The findings highlight the importance of monitoring TEC as an indicator of solar-ionospheric interaction. The observed disturbances may serve as a foundation for further studies of near-Earth space dynamics and contribute to the understanding of processes within the Sun–Earth system.

Peculiarities of the Geospace Storm of September 11–21, 2024

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The study of space weather and geospace storms is an important interdisciplinary issue. Its variations are usually driven by solar storms, which cause disturbances in the magnetosphere, ionosphere, atmosphere, as well as in magnetic and electric fields. Each storm exhibits unique characteristics depending on the features of the solar storm, the phase of the solar cycle, the season, the time of day, the geographic location, the observation methods etc.

The aim of this study is to demonstrate the capabilities of the developed format for comprehensive solar activity and space weather analysis across all subsystems of the Sun–interplanetary medium–magnetosphere–ionosphere–atmosphere–Earth system, using the storm of September 11–21, 2024, as an example. The format covers more than 60 time-dependent key parameters. Assessed effects of the solar and geospace storms, and their components (magnetospheric, ionospheric, atmospheric, electric, and magnetic storms).

On September 12 and 14, 2024, X1.3 and X4.54 class solar flares occurred, accompanied by coronal mass ejections (CMEs), which upon reaching Earth's magnetosphere, triggered a geospace storm. The flares had power levels near Earth of 16.6 GW and 57.9 GW, transferring 9.5 TJ and 73 TJ of energy, respectively. The CMEs triggered disturbed solar wind flows with speeds near Earth up to 583 km/s, particle density up to 3.9×10^7 m^{-3} and plasma temperature of 9.7×10^5 K for the first flare, while the second CME had lower particle density of 1.55×10^7 m^{-3} and temperature of 6.27×10^5 K, despite a slightly higher speed of 595 km/s. The solar storm was also accompanied by the injection of solar cosmic rays, reaching power of 760 GW and 490 TJ energy for the first burst, and 714 GW and 513 TJ for the second respectively.

The first burst of disturbed solar wind (21-hour duration) subjected the magnetosphere to dynamic, magnetic, and thermal pressures, with power reaching 94 TW, 2.24 TW, and 3.1 TW, and energy values of 2.8 EJ, 74 PJ, and 30 PJ, respectively. The second burst (24-hour duration) produced 53.1 TW, 1.1 TW, and 0.5 TW, with 2.1 EJ, 42.8 PJ, and 14.1 PJ, respectively.

The energy of the magnetospheric storm is described by Akasofu's ε_A parameter, with observed peak values of 0.62 and 0.32 TJ/s for the first and second storms, respectively. The Chapman–Ferraro radius from typical quiet value 10 R_E, decreased during the storms to approximately $R_{CF} \approx 6.77$ R_E at 10:06 UTC on September 12 during the first storm surge, and to about $R_{CF} \approx 7.59$ R_E at 01:10 UTC on September 17 during the second storm surge.

The magnetic storm was characterized by interplanetary magnetic field (IMF) components *By* and *Bz* oscillations within ±25 nT. Substantial fluctuations in the SYM-H index have been observed, reaching minima of –128 nT around 18:50 UTC on September 12 and –144 nT at 04:23 UTC on September 17, 2024. The total energy of the magnetic storms was estimated at 5.48 PJ and 5.58 PJ for the first and second surges, respectively. The associated power during the sharp decline in the *Dst* index over a 9-hour interval was approximately 0.17 TW for both storms.

The ionospheric and atmospheric storms were characterized by significant negative disturbances at high latitudes, peaking on September 14 and 17, with a gradual weakening at lower latitudes. In the mid-latitude European region, a negative ionospheric storm was observed, with an I_{NIS} index of up to 6–7.6 dB. The atmospheric storm was marked by a decrease in the $\sum O/N_2$ ratio from undisturbed values of 0.6–1.0 to 0.2–0.4 during both bursts, followed by a gradual recovery.

Global changes in total electron content during the unique ionospheric storm of May 10–12, 2024

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The paper is devoted to the study of global variations in the total electron content (TEC) in the ionosphere that accompanied the unique geospace storm of May 10–12, 2024.

An ionospheric storm, as a component of a geospace storm, is an important link in the Sun–interplanetary-medium–magnetosphere–ionosphere–atmosphere–Earth system and has a significant impact on the operation of space and ground-based systems. The storm triggers numerous processes in the ionosphere, the quantitative characteristics of which have not yet been sufficiently studied. Primarily, these include several-fold increases or decreases in electron density in the ionosphere (positive or

negative storms), the intensification of the auroral electrojet, increased plasma particle recombination rates due to enhanced Joule heating at high latitudes, and the fountain effect at the magnetic equator, which leads to the formation of maxima near ±20° latitudes and the expansion of the crest in the equatorial ionization anomaly. Studies of these ionospheric processes generally provide qualitative descriptions and rely on global ionospheric TEC maps with a temporal resolution of 1 h and a spatial grid step of 5°×2.5° in longitude and latitude, respectively, which are not suitable for investigating details of individual ionospheric anomalies. The additional use of data from networks of vertical sounding instruments or incoherent scatter radars does not significantly improve the observation of specific details within these global processes.

The purpose of this work is to quantitatively assess the disturbance parameters induced by storm-related processes and to study the details of TEC behavior in the ionosphere along the measurement point trajectories with a temporal resolution not exceeding 30 seconds.

This study uses a research method based on measuring the TEC using signals from navigation satellites. The area of investigation is the ionosphere along the 68°W and 112°E meridians. Data were collected from 40 signal receiving stations located near the selected meridians for 32 GPS satellites during the unique ionospheric storm that occurred from May 9 to 12, 2024 (with the geomagnetic storm classified as G5). The utilization of a large number of TEC time series along the chosen meridians provides a more comprehensive and accurate depiction of ionospheric behavior during the storm.

As a result of the data processing, tens of thousands of TEC time series along the measurement trajectories in the ionosphere near the selected meridians were obtained. Diverse ionospheric responses to the storm were identified. In particular, during the negative phase of the storm, TEC reductions reached 120–140 TECU, whereas during the positive phase, the decrease did not exceed 50 TECU. Within the region of the equatorial ionospheric anomaly, TEC increased from 10 to 150 TECU (latitudes ranging from –40° to +50°). The fountain effect enhanced TEC at latitudes between ±15° and ±20°, simultaneously depleting TEC along the magnetic equator. The process of ionospheric plasma transport from the magnetic equator occurred in discrete portions, each lasting approximately two hours.

Solar wind parameters during a unique geospace storm on May 8-14, 2024

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The period of May 8–14, 2024, was marked by one of the most powerful geospace storms of recent decades, triggered by a series of coronal mass ejections (CMEs) that reached Earth with significant energy. This event caused substantial disturbances in the magnetosphere, ionosphere, atmosphere, and even the lithosphere. Of particular interest is the analysis of solar wind parameters, which serve as the primary energy source for subsequent chain reactions in the geospace environment.

The aim of this work to conduct a system spectral analysis (SSA) of solar wind and interplanetary magnetic field (IMF) parameters during the storm of May 10–12, 2024. The initial data were subjected to bandpass filtering (BF) and SSA, which involves a combined application of short-time, adaptive Fourier transforms and wavelet transforms with a chosen Morlet function as a basic function.

For the analysis, interplanetary environment data from NASA OMNIWeb (https://omniweb.gsfc.nasa.gov/form/omni_min.html) were used, including parameters such as solar wind velocity (V_{sw}), density (n_{sw}), temperature (T), dynamic pressure, and the IMF. The data were processed at 1-minute intervals and averaged daily to identify general trends.

The variations of key solar wind parameters during the unique geocosmic storm of May 8–14, 2024, were analyzed using BF and SSA. A sharp increase in the amplitudes of the B_y- and B_z-components of the IMF—to 70–74 nT and 50 nT, respectively—was observed during the main phase of the storm (May 10–11), along with a secondary intensification of disturbances on May 12. Solar wind speed rose to 1026 km/s, density peaked at 60 cm^{-3}, dynamic pressure reached 50 nPa, and temperature increased to 2.1×10^6 K. All parameters exhibited quasi-periodic variations with dominant periods ranging from 60 to 190 minutes.

These results highlight the presence of strong quasi-periodic activity throughout all storm phases and confirm the high energy content of processes occurring in the interplanetary environment during this period. They also underscore the importance of comprehensive solar wind analysis for early forecasting of geospace storm effects and for clarifying the mechanisms by which such storms impact various geophysical domains.

Manifestations of the extreme geospace storm of May 10–12, 2024 at Ukrainian Antarctic station Akademik Vernadsky

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The purpose of this paper is to examine the manifestations of the significant storm features in the geomagnetic field at high latitudes. The analysis is based on the data collected at the magnetometer stations Akademik Vernadsky (AIA) and Casey Station (CSY), both in Antarctica.

AIA Station (65.2450 S, 64.2580 W). This station is located in the western hemisphere. Until 17:15 UT on May 10, 2024, the peak-to-peak amplitudes of fluctuations of the *X*-component strength were smaller than ~100 nT, whereas between 17:15 UT and midnight they increased to approximately 1000 nT and attained ~2000 nT the next day. At the beginning of the day on May 12, 2024, they occasionally increased to 600 nT and were within ~50 nT on the days used as a quiet time reference. The peak-to-peak amplitudes of fluctuations in the *Y*-component reached 700 nT between 17:15–24:00 UT on May 10, 2024, but were greater than 1400 nT until 08:00 UT on May 11, 2024, though were relatively small after 16:00 UT. The peak-to-peak amplitudes of fluctuations increased to ~300 nT only at the beginning of May 12, 2024, whereas on the days used as a quiet time reference, they were smaller than ~40 nT. The *Z*-component strength after 17:15 UT on May 10, 2024, first sharply decreased by almost 400 nT, and then increased at the end of the day to ~400 nT. The next day, the peak-to-peak amplitudes of fluctuations increased to ~1200 nT, which continued from 00:00 UT through to 12:00 UT. After 12:00 UT, the peak-to-peak amplitudes of fluctuations did not exceed ~300 nT; at the beginning of May 12, 2024, they attained ~700 nT, whereas during the days used as a quiet time reference, they were usually within ~60 nT.

CSY Station (66.2830°S, 110.5330°E). This station is located in the eastern hemisphere. Prior to about 17:15 UT on May 10, 2024, the peak-to-peak amplitudes of fluctuations in the *X*-component strength did not exceed ~50 nT, whereas they increased to ~800 nT between 17:15 UT and 24:00 UT, and persisted little altered (750 nT) for the next ~24 h. On May 12, 2024, the peak-to-peak amplitudes of fluctuations approached ~350–400 nT, whereas on the days used as a quiet time reference, the peak-to-peak amplitudes of fluctuations usually did not exceed 50 nT; only on May 17,

2024, they attained 200–300 nT. A noticeable (up to 200 nT) variation in the *Y*-component strength occurred on the morning of May 10, 2024. Over the time interval 17:15–24:00 UT on May 10, 2024, the peak-to-peak amplitudes of fluctuations increased to ~1100 nT. The next day, they attained ~1200 nT. At the beginning of May 12, 2024, they approached 700 nT, and at the end of the day they were confined to 300 nT. On the days used as a quiet time reference, the peak-to-peak amplitudes of fluctuations were smaller than 30–50 nT; however, on May 17, 2024, they attained ~200 nT. The peak-to-peak amplitudes of fluctuations in the *Z*-component strength did not exceed ~100 nT until 17:15 UT on May 10, 2024, whereas afterwards the behavior of time variations changed drastically: the *Z*-component strength showed a few sharp drops overall by almost ~700 nT over a prolonged period of time, with an overall non-monotonic increase from –700 nT to +300 nT and a peak-to-peak amplitude approaching ~1000 nT. On May 11, 2024, the peak-to-peak amplitudes of fluctuations were only about 600 nT, and remained almost unchanged (590 nT) on May 12, 2024. On the days used as a quiet time reference, the peak-to-peak amplitudes of fluctuations usually did not exceed 50–100 nT, whereas they attained 200–300 nT on May 17, 2024.

Extreme geomagnetic storm of May 10–12, 2024: Latitudinal and longitudinal features

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The purpose of this paper is to examine the geomagnetic field features of the latitudinal and longitudinal manifestations of this extreme geomagnetic storm with D_{st} of –412 and K_p of 9. The analysis is based on the measurement data collected at thirteen International Real-time Magnetic Observatory Network (INTERMAGNET) magnetometer stations (https://imag-data.bgs.ac.uk/GIN_V1/GINForms2), arranged in two meridional chains in the western (5 stations) and eastern (8 stations) hemispheres. The northward, *X*, eastward, *Y*, and vertical, *Z*, component measurements were acquired with about 1 nT error, a 1 nT strength resolution, and at 1 min step. The moving averages for 24 hours were subtracted from the raw data acquired at each magnetometer station

producing temporal variations in the strength of all components of the geomagnetic field, which were further subjected to an analysis.

The geospace storm was caused by variations in the dynamic pressure of the solar wind and its power has been estimated to be ~0.4×10^{15} W, which yields energy of ~6.5×10^{18} J for a burst of 8 h duration. The power of the magnetospheric storm, which is determined by the pressure of the interplanetary magnetic field, has been estimated from the Akasofu's epsilon parameter equal to ~15×10^{12} J/s, resulting in energy of 2.7×10^{17}J for a burst of 10 h duration. The energy of the geomagnetic storm (GMS) is determined from the value of D_{st}-index. For $D_{st\min} = -412$ nT and the geomagnetic storm main phase of 4 h duration, one has a maximum power of 1.4×10^{12} W, energy of 20×10^{15} J.

The extraordinary character of the GMS of May 10–11, 2024, is established via the comparison of its parameters with those of April 23–24, 2023, and with the maximum possible parameters of a super-unique storm, which is apparently the storm termed the Carrington event (September 1–2, 1859). The salient parameters of GMSs of May 10–11, 2024; April 23–24, 2023; and of the storm termed the Carrington event corresponded to *Kp*-indices equal to 8+, 9, and 11, respectively. Also, the D_{st}-index reached a minimum value of –212 nT during the storm of April 23–24, 2023, which is by a factor of approximately 2 greater than $D_{st} = -412$ nT during the storm of May 10–11, 2024. The energetics parameters of the storm of May 10–11, 2024 are by a factor of several times greater than the energetics parameters of a severe storm of April 23–24, 2023 (G4-class storm, according to the NOAA space weather scales). Therefore, the storm of May 10–11, 2024, is classified as extreme (G5-class storm). During the storm of May 10–11, 2024, the *X*-, *Y*-, and *Z*-components were enhanced by a factor attaining 30–60, 30–36, and 38–43, respectively, whereas such increases during of the severe storm of April 23–24, 2023, do not exceed a factor of 10. The latitudinal dependence of the magnitude of the disturbance in the strength of all geomagnetic field components has shown that a clear tendency of the PtPAF to decrease with decreasing latitude is observed in the Eastern Hemisphere, while this tendency also takes place in the Western Hemisphere, however it is expressed less clearly (due to a small number of stations). The analysis of the local time dependence of variations in the geomagnetic field strength on May 10–11, 2024, which was based on the data from stations situated in the areas under conditions of both polar day and night, revealed qualitative and quantitative differences existing between the variations.

Thus, the study reveals significant latitudinal dependencies, hemispheric asymmetry in electrojet responses, extreme energy deposition (6.5×10^{18} J

for the geospace storm), and clear diurnal differences in geomagnetic fluctuations between hemispheres.

Parameters of infrasound signals generated by the explosive eruption of Tonga volcano on January 15, 2022: results of observations at Ukrainian stations

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Infrasound is frequently generated by natural phenomena, for example, volcanic eruptions, earthquakes, ocean waves, and meteorological disturbances etc., as well as by anthropogenic sources such as explosions, rocket and aircraft flights, and industrial activities.

This study aims to analyze the global propagation characteristics of infrasound waves generated by the explosive eruption of the Tonga volcano at 04:15 UT on January 15, 2022. The investigation is based on data collected from a network of Ukrainian infrasound stations. A comprehensive theoretical analysis of the various physical effects induced by this eruption was performed recently. Pressure variations were examined using data from three stations (Kamianets-Podilskyi, Luhansk, and Horodok) with distances between the eruption source and the observation points ranging from 15.6 to 16.3 Megameters (Mm). For illustrative purposes, detailed parameters of infrasound variations at two stations are discussed below.

Band-pass filtering of the infrasonic data from the Horodok station revealed three distinct delay times, measured over a propagation distance of 56 Mm, of 180,900 s, 202,500 s, and 213,300 s. These delay times correspond to infrasound arrival speeds of approximately 310 m/s, 277 m/s, and 267 m/s, respectively. The amplitude of the observed signals ranged from 20 to 30 Pa.

At the Luhansk station, two groups of infrasound signals were detected. One group, associated with a Lamb wave, exhibited a propagation speed of 304 m/s, while the second group (linked to an acoustic wave) propagated at 270 m/s. Each group contained ultra-wideband signals with dominant periods in the ranges of 400–600 s and 800–900 s, respectively.

At both stations, the highest propagation speed is characteristic of an atmospheric Lamb wave, whereas the lower speeds are indicative of infrasound propagation in the tropospheric and stratospheric layers.

System spectral analysis further indicated that oscillations with periods between 400 and 600 s, 850 and 950 s, and durations ranging from 60 to 180 minutes predominated.

Interference in the atmospheric communication channel triggered by the Tonga volcano eruption was observed for more than two days. Variations in atmospheric pressure amplitude reached magnitudes of tens of Pascals. These observed effects were attributed to the Lamb wave as well as to infrasound propagating through stratospheric and thermospheric waveguides. The findings demonstrate that the eruption induced significant atmospheric disturbances that circled the Earth twice (covering more than 40 Mm) and persisted for over two days.

Ground-based microwave radiometer data processing software and application for stratospheric and mesospheric altitude profile and wind retrievals

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Microwave radiometers have great potential in remote sensing technology and can be used to measure the vertical distribution of gases in the stratosphere and mesosphere. We have developed and operated a 110/115 GHz microwave radiometer to measure ozone and carbon monoxide in the atmosphere simultaneously. This ground-based microwave radiometer is the only method capable of all-weather, all-time observation of the upper atmosphere. Wind speed is an essential parameter for describing the dynamics and energetics of the middle and upper atmosphere. Understanding the momentum and energy transfer processes of different neutral and ionized particles in the upper atmosphere is significant and can support space environment prediction. Therefore, using microwave

technology to measure atmospheric wind speed has become a research hotspot, especially in the mesosphere. For microwave measurement data processing, we have developed a user-friendly interface that integrates several independent programs, allowing researchers to avoid multiple iterations and speed up the data processing. The software has developed and incorporated methods for obtaining wind parameters in the stratosphere and mesosphere. By combining these two tools - microwave instruments and data processing software - the synergy of various instruments used by multiple research groups can be achieved. For this purpose, we have developed the ARTS Graphical User Interface (ARTSGUI) software based on the ARTS code package and forward calibration program. This software can visually process the calibration and inversion of radiometer data, including multiple profiles. That simplifies and speeds up the processing process and avoids many errors caused by multi-step manual data input. The results of the data processing software application for the inversion of height profiles and wind parameters in the stratosphere and mesosphere are discussed in this report.

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Main features of ionospheric disturbances during strong geospace storm on November 4–5, 2023

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The investigation of the phenomena and mechanisms occurring during geospace storms holds considerable significance, not only from a purely scientific or academic perspective but also in terms of practical applications. During intense geospace storms, vast amounts of energy are transferred into the Earth's magnetosphere, ionosphere and atmosphere through solar wind particles and electromagnetic radiation. This influx of energy leads to its accumulation and subsequent release, inducing substantial alterations within the subsystems of the Earth–Atmosphere–Ionosphere–Magnetosphere (EAIM) framework. These perturbations, in turn, influence the dynamics of interactions among these subsystems. Consequently, such changes critically affect the performance of various technological systems. A comprehensive understanding of the processes and effects transpiring within the EAIM

system, particularly in the ionosphere, during geospace storms is instrumental for optimizing and enhancing technological devices across multiple domains and advancing knowledge of ionospheric and magnetospheric structures.

In the present study, we analyzed a comprehensive set of key indicators that describe the state of space weather and the conditions within the magnetosphere and ionosphere separately. These indicators include: the concentration of solar wind particles, proton temperatures within solar wind clouds, solar wind particle velocities, the dynamic pressure of solar wind particles on Earth's magnetosphere, the B_Y- and B_Z- components of the Interplanetary Magnetic Field (IMF), the Akasofu parameter, the Kp index, the Dst index, components of the geomagnetic field (SYM-H, SYM-D, ASY-H, and ASY-D), and geomagnetic auroral activity indices (SME, SMU, SML). Furthermore, we incorporated global ionospheric maps (GIM) to track the dynamics of the Total Electron Content (TEC), time-series data of TEC recorded at GNSS receiving stations along two meridians, as well as ionospheric scintillation indices, both in terms of phase and amplitude.

The observation period spanned six days, encompassing two days preceding the storm (November 2 and 3, 2023), the storm's main phase (November 4 and 5, 2023), and two days during the recovery phase (November 6 and 7, 2023). The key findings reveal a marked increase in TEC values, particularly evident in equatorial and mid-latitude regions, where peak deviations reached 40–60% above baseline conditions. Ionospheric scintillation activity also intensified notably during the main phase of the storm, signifying the emergence of small-scale ionospheric irregularities. Global Electron Content (GEC) exhibited pronounced enhancement during the storm's peak, followed by a substantial decline during the recovery phase, eventually stabilizing at pre-storm levels. This observed behavior may be indicative of accelerated recombination processes within the thermosphere–ionosphere system.

On the magnetospheric front, significant disturbances were identified within the ring current and auroral electrojet systems. The SYM/H and ASY/H/D indices displayed the classical signatures of storm-time dynamics, characterized by sharp declines and noticeable asymmetries, reflective of energetic particle precipitation and alterations in current systems. The SME, SMU, and SML indices corroborated elevated auroral activity, predominantly on the nightside, with spatiotemporal patterns aligning with typical substorm evolution scenarios.

Analysis of indoor-outdoor aerosol air quality in Changchun, China

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Particulate matter (PM) is an air pollutant negatively affecting human health. Although China has continuously improved air quality through governance in recent years, research has shown that air pollution caused by $PM_{2.5}$, PM_{10}, and PM_1 still can be significant. Particulate matter may originate from indoor and outdoor sources. For example, these sources are indoor cooking, dust removal, outdoor vehicles, and industry and heat emissions. According to a study, the behaviour of opening windows can cause outdoor particulate matter to enter the room, which inevitably affects the concentration of indoor particulate matter. In addition, seasonal changes can also affect the concentration of aerosols in the air at any location.

This study explores the relationship between indoor and outdoor $PM_{2.5}$, PM_{10}, and PM_1 concentrations in Changchun and analyzes which factors could affect air quality. This study measured indoor and outdoor PM concentrations ($PM_{2.5}$, PM_{10}, and PM_1) in different regions (JiDa and Nanling) of Changchun City from 2023 to 2025 using IQAir and PurpleAir network sensors, respectively. The final results indicate that: (1) the outdoor particulate matter concentration in Changchun city is severely affected by westerly winds; (2) the indoor PM concentration increases during the winter heating period; (3) neighbors' cooking in houses influence significantly indoor air quality due to specific ventilation system in the buildings. In addition, the concentration of indoor particulate matter also increases with the increase of outdoor PM concentration and dependent on close/open window.

Stratosphere–troposphere coupling during extreme cooling in Alaska in 1989: case study

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The extremely cold weather in Alaska in January 1989 is analyzed by comparing observed surface temperature with the distributions of the stratospheric and tropospheric temperature and total ozone from reanalyses. The results show the association of a regional stratospheric warming, which accompanied the anomalous total ozone increase, with the transformation of the vertical temperature profile. The isotherm transformation occurred between the middle stratosphere and the surface and resulted in the formation of a meridional temperature minimum in the troposphere in the Alaskan region. In the absence of a significant correlation between the local surface temperature and pressure, the results suggest the possible thermal influence of the stratosphere on the observed weather anomalies, both in strong cooling in late January and anomalous warming in early January and early February 1989. A detailed explanation of the vertical temperature profile transformation between the middle stratosphere and the surface during the occurrence of the extremely cold weather is discussed and requires additional analysis. These results are consistent with the mechanism of stratospheric forcing of extreme surface cooling in the midlatitudes described in recent studies.

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27-day variations of zonal wind in the troposphere of the northern and southern hemispheres

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Due to global warming and the possible role of solar activity (SA) in this process, interest in the influence of SA on weather and climate of the Earth has increased significantly. Most investigations are traditionally based on the study of the 11-year solar cycle. In our studies, 27-day solar-induced variations of zonal wind and other atmospheric parameters in the Northern Hemisphere were established for the first time. It is shown that the influence of SA is realized through tropospheric-stratospheric interaction, which is supported by the upward propagation of planetary-scale Rossby waves. The Northern and Southern Hemispheres differ significantly in the level of planetary waves activity, therefore, expanding the consideration of solar-tropospheric associations to the Southern Hemisphere will allow us to clarify the role of the dynamic (wave) mechanism in this process.

The aim of the work is to compare the characteristics of the response of the troposphere of the Northern and Southern Hemispheres to 27-day cycles of SA and to clarify the role of wave activity in these processes. The study was conducted using daily solar and atmospheric data for twenty 27-day solar cycles for 2002–2004. Data on zonal wind, u, and atmospheric temperature, T, were used at 15 altitude levels from 1000 to 10 hPa, covering the troposphere and lower stratosphere (website https://psl.noaa.gov/data/timeseries/daily/). To estimate SA, the $F_{10.7}$ index was used (website https://www-app3.gfz-potsdam.de). Calculations were performed using superposed epoch analysis.

It was found that the most significant 27-day wind variations are observed in 4 longitudinal sectors: European/African, Pacific, American and Atlantic. In general, this property is inherent in both hemispheres both in winter and summer, despite the significantly different activity of low-frequency Rossby waves for these conditions.

The altitudinal and latitudinal pattern of disturbed wind anomalies in the indicated longitudinal sectors is characterized by the presence of usually 6, sometimes 7–8 sign-changing anomalies with maximum amplitude in the upper troposphere; at high latitudes, wind anomalies are also significant in

the stratosphere. These changes lead to periodic displacement of jet streams along the latitude. Most often, anomalies with an amplitude of 5–12 m/s are observed at high and middle latitudes, and up to 5 m/s at low latitudes. 27-day variations in zonally averaged wind speed are several times smaller.

The assessment of Rossby wave activity using stratospheric temperature data indicates the role of waves with zonal wave numbers m = 1–4 in the mechanism of solar influence. The expansion of the frequency range of Rossby waves and their nonlinear interaction are able to provide two-way dynamic (wave) interaction of the troposphere and stratosphere not only in winter (according to the Charney-Drazin criterion) and allow us to explain the similarity of the influence in the Northern and Southern Hemispheres with significantly different activity of low-frequency Rossby waves.

The work partially has been supported by a Ukraine state-funded research projects (grant no. 0124U000461, 0124U000478).

Total ozone over Europe from ground-based, satellite and reanalysis data

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We have processed the total ozone column series for more than 40 European observational stations using measurements of various ground-based and satellite instruments and MSR-2 reanalysis data. Dobson spectrophotometers and Brewer spectrometers equip the ground-based network, but some filter observations were also carried out. The reanalysis is available from 1960, but it is considered more reliable from 1979, when systematic global measurements by the Total Ozone Mapping Spectrometer were begun. We have analyzed seasonal variations, long-term changes, and differences between various data series. Particularly, the properties of the Kyiv-Goloseyev station results are studied as well.

Seasonal variations are predominantly similar for all the European stations, with a yearly maximum in March–April and a minimum in

October–November. Several stations have demonstrated an unusual dependency due to their low quality of measurements, mainly by non-standard instruments. Typically, seasonal variations are qualitatively approximated by third or fifth-order polynomials. The total ozone values increase to higher latitudes, and an unexpected feature is a double structure of the seasonal maximum, observed at the high latitude stations, including Scandinavian ones. Long-term ozone variations show minimal values in the mid-1990s.

It is essential to analyze the discrepancies between different data series. Typically, a comparison with ground-based measurements allows validating satellite data, but this approach can also trace possible problems in the ground-based data quality. In particular, data from some Dobson instruments showed total ozone underestimation of 10 Dobson Units or more near the winter solstice. This inconsistency is probably caused by using AD wavelengths data at high zenith angles while the shortest A pair has low intensity. Plotting this difference in dependence on the day of year demonstrates a specific parabola-type curve. The Kyiv-Goloseyev data do not show any evident yearly changes in the satellite–ground–based differences.

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Statistical characteristics of the atmospheric and oceanic tsunami generated by the Tonga volcano explosive eruption on January 15, 2022

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A tsunami is a destructive wave caused by underwater earthquakes, volcanic eruptions, landslides, avalanches, powerful atmospheric processes, the impact of large celestial bodies, significant underwater explosions or meteorological changes. Tsunamis generated by atmospheric processes, such as weather fronts, hurricanes (typhoons), and squalls, are referred to as meteotsunamis. Additionally, tsunamis produced by powerful atmospheric waves (known as Lamb waves) are called atmospheric tsunami waves.

Over time, as humanity has faced the consequences of numerous tsunami disasters, there has been a growing recognition of the need to prevent and mitigate these catastrophic events.

The purpose of this report is to present the main tsunami parameters, their simulations and consequences, as well as statistical characteristics of atmospheric and oceanic tsunami waves for the most remote observation stations (8–9 Mm) from the Hunga Tonga–Hunga Ha'apai volcano in the Pacific region, located in both the open ocean and marginal sea. The Tonga volcano is a submarine volcano (20°54′S, 175°38′W) in the Kingdom of Tonga. The crater is roughly 200 m below sea level and the caldera is 4–5 km at its widest extent. Five underwater explosions were observed to occur over the 04:00–05:00 UTC period on 15 January 2022, with the second explosion at 04:15 UTC being the most powerful. The gas emissions reached 50–58-km altitude producing the highest recorded eruption column. The mass of the erupted material attained 2.9 Gt and their volume 1.9×10^9 m^3. The explosive energy was estimated to be in the range from 4–18 Mt of TNT to 478±191 Mt of TNT.

Well-known methods of mathematical statistics (scatter diagrams, regressions) were used to analyze the observational data retrieved from real-time tsunami monitoring systems.

The calculation results confirm well the main regularities obtained from the statistical analysis of observational data. Tsunamis with a speed of approximately 312 m/s were generated by an atmospheric Lamb wave. The speeds of these atmospheric tsunami waves in both the open ocean and the marginal sea were nearly identical and showed no dependence on the characteristics of the water body. A slower tsunami wave, confirmed to have originated from the ocean, was directly generated by the underwater explosion of the Tonga volcano. This tsunami in the open ocean traveled at a speed of 203 m/s, in the marginal sea the speed decreased to 180 m/s. The speed of the oceanic tsunami wave was entirely determined by the depth of the reservoir. The ratio of tsunami height to its amplitude differed from 2 by no more than 10%. In both the open ocean and marginal sea, the height and amplitude of a tsunami of oceanic origin were several tens of percent higher than those of a tsunami of atmospheric origin. These parameters primarily depended on the topography of the reservoir and coastline. Simulation have shown that powerful tsunamis with an amplitude of several meters on the coast are capable of flooding significant areas located at a distance of ~0.1–1 km from the coast. Tsunamis with amplitudes of ~0.1–0.3 m did not pose a serious threat, since they are capable of running ashore at a distance of no more than 2.8–12 m.

HISTORY OF ASTRONOMY

Ukrainian Nanosatellites “POLYITAN” Conquer Space

L. Bashtova

The State Polytechnic Museum named after Boris Paton at Kyiv Polytechnic Institute named after Igor Sikorskyi, Kyiv, Ukraine

Today, not only large enterprises, but also leading scientific and educational institutions can develop and manufacture spacecraft. This became possible thanks to the rapid development of the element base and the high qualification of technical specialists.

Kyiv Polytechnic Institute named after Igor Sikorskyi (KPI) has been actively developing its own spacecraft development direction for more than ten years. One of his most successful developments was the PolyITAN series of nanosatellites. These compact CubeSat spacecrafts became the first university satellites in Ukraine. A group of young specialists from KPI, led by scientist Boris Rassamakin, is working on their development.

The success story of the "PolyITAN" series began with PolyITAN-1, launched into Earth orbit in 2014. This single-block nanosatellite (1U CubeSat) measuring only 10x10x10 cm has become a real long-liver, significantly exceeding its planned annual service life. His successful work proved the reliability of the design developed at KPI.

Among the most successful solutions in PolyITAN-1 were: solar panels that had a high efficiency, as well as a telemetry system, a GPS system of original design, etc. The purpose of the satellite launch was to work out technological flight modes and study the impact of outer space on the operation of its electronic subsystems.

The next step was PolyITAN-2-SAU, launched in 2017 as part of the international space project to study Earth’s climate change (QB50). This apparatus was larger in size (consisted of two cube blocks, 10x10x20 cm) and had equipment on board to measure atomic oxygen in the upper atmosphere. Atomic oxygen is the main element at an altitude of 90-420 km from the Earth’s surface, so measuring its characteristics is very important. These studies allow you to create models of the thermosphere and assess its state at certain distances. The data collected by him were important for the international scientific community, in particular in the field of aerospace research and the development of launch vehicles. For this nanosatellite, KPI developed a special orientation system with solar sensors, and solar battery frames were also specially designed.

In January 2023, PolyITAN-HP-30 was launched into orbit. This is a typical two-block nanosatellite of cubic shape. Its development was dedicated to the 30th anniversary of Ukraine's Independence. This nanosatellite was used to conduct a scientific experiment to study the efficiency of heat pipes developed at KPI for thermal stabilization systems of spacecraft. To track the flight of the nanosatellite and conduct planned research, a Centre with the necessary testing equipment was created at KPI.

Another ambitious project is currently under development – PolyITAN-12U. This twelve-block CubeSat nanosatellite (20x20x30 cm in size) will be the first Ukrainian university spacecraft of this scale designed for remote sensing of the Earth. Its payload will be an optical scanner with high spatial resolution. It is expected to be able to transmit valuable data for agriculture, emergency services and other needs. The launch of PolyITAN-12U is scheduled for 2025.

Specialists of the KPI are working on the development of a satellite that will monitor the Earth's ozone layer. This device is being developed jointly with the Poznan Polytechnic Institute. There are other projects that the institution considers promising. Today, the BioSat project has already been conceptually developed. There will be plants in its capsule. Thanks to space experiments, it will be possible to study how they develop in zero gravity and high radiation. Another upcoming project, GraviSat, will help study the fluctuations of the Earth's gravitational field.

PolyITAN satellites can be used in the future to collect data about the Earth's surface, to monitor meteorological conditions, and to conduct observations of space objects.

Under the CubeSat program, KPI actively cooperates with universities and organizations of other countries. At the same time, the educational institution demonstrates the innovative potential of our country in the international arena and trains highly qualified specialists, with modern knowledge and practical skills, for the space industry of Ukraine.

The world's first Baikonur cosmodrome is 70 years old (02.06.2025)

S. Grachev

Boris Paton State Polytechnic Museum
at Igor Sikorsky Kyiv Polytechnic Institute

The word "cosmodrome" - to denote the place where the journey into space begins, was first used by one of the pioneers of world cosmonautics, A.A.

Sternfeld (1905-1980), in his book "Introduction to Cosmonautics", published in France in 1934.

In 1954, the USSR, under the leadership of Chief Designer S.P. Korolev, began designing a new intercontinental ballistic missile R-7 with a flight range of over 8 thousand kilometers. The preliminary design of the ICBM was considered by the Interdepartmental Expert Commission under the leadership of Academician M.V. Keldysh. To prepare and carry out its launches, it was necessary to find a place for a missile range.

Its search was carried out by a commission under the leadership of General V.I. Voznyuk. Several options were considered, including the territory of Western Ukraine. The final decision was influenced by the weighty considerations of S.P. Korolev - to place the landfill in the Aral Karakum desert of Kazakhstan. The commission decided on its exact location - near the Tyura-Tam semi-station of the West Kazakhstan Railway.

Construction began in 1955 in a completely uninhabited place, where people had not lived for a long time due to harsh natural conditions. The construction was led by military civil engineer G.M. Shubnikov. The founding day of the test site was established on June 2, 1955, when the organizational and staff structure of the "Research and Testing Site No. 5 of the USSR Ministry of Defense" was approved. General O.I. Nesterenko was appointed its first chief. Since 1961, after the first flight of a person into space from it - Yu.O. Gagarin, the test site has received the world-famous name "Baikonur Cosmodrome".

The history of Baikonur has been going on for 70 years, with periods characterized by certain qualitative changes in its structure and activities. There are ten of them: the first – 1955-1957; the second – 1957-1960; the third – 1960-1963; the fourth – 1963-1965; the fifth – 1965-1975; the sixth – 1975-1991; the seventh – 1991-1994; the eighth – 1994-2010; the ninth – 2010-2015; the tenth – 2015-2025.

Baikonur is the first and largest cosmodrome in the world. It went down in history with its priority achievements in world astronautics. Having opened the space era of mankind, it has carried out launches from a series of "firsts in the world", of which there are more than 40, starting with the launch of the first artificial satellite of the Earth, ending with the docking in orbit of large-mass spacecraft. No other cosmodrome in the world, of which there are currently 36, can boast of this! In addition, about 120 launches of automatic interplanetary stations to the Moon, Mars, and Venus were carried out from it. Not all of them were successful, but for the first time, people saw these celestial bodies up close, and not through the eyepiece of a telescope!

Astronomy in museum work on the example of the work of a school museum

V. Datsyuk

Vysokopytsky Lyceum of Zhytomyr District, Zhytomyr Region, Ukraine

The Vysokopytsky Museum “Colors of Strategic Polissya”, whose area is about 1000 sq.m., has two exhibition sections: “Our Polissya Region”, “Our Victorious Region”, which house 23 exhibitions, over 8 thousand exhibits.
The museum is located at 12427, ul. Kalynova 1, Vysoka Pich village, Teterivska AH, Zhytomyr District and has the status of: an exemplary museum of an educational institution, is not a legal entity, has the status of a school museum of the Vysokopytsky Lyceum.

Other exhibitions include: “Through Thorns to the Stars” – the history of the development of astronautics; “Our Rocket Garrison” – the history of the Vysokopytsky Nuclear Rocket Base of the Vysokopytsky Rocket Garrison; "Astronomical Memorial" is dedicated to outstanding astronomers - our fellow countrymen.

The last mentioned exposition tells about astronomers of our region. This is Ivashchenko Yuriy Mykolayovych - founder of the first astronomical observatory in the Zhytomyr region "Lypnevyi ranok"; Nadubovich Yuliy Arkadiyovych - researcher, discoverer of the coastal effect of the aurora; Jun’ Yosyp Volodymyrovych - astronomer and geodesist, author of the non-classical theory of calculation errors, graduate of Vysokopytsk secondary school.

The museum cooperates with the National Museum of Cosmonautics named after S.P. Korolev, Zhytomyr; Poltava Museum of Aviation and Cosmonautics named after Y. Kondratyuk; astronomical museum of the Kyiv Astronomical Observatory.

Volodymyr Volodymyrovych Telnuk-Adamchuk: From Metallurgist to Astronomer

G. Ivanova

Borys Paton State Polytechnic Museum
at Ihor Sikorskyi Kyiv Polytechnic Institute, Ukraine

Volodymyr Volodymyrovych Telnuk-Adamchuk was born on November 4, 1936, in the village of Iskrivka, Zaporizhzhia region, into the family of an agronomist. Due to his father's profession, which required frequent relocations between various industrial enterprises, Volodymyr experienced a childhood full of change and movement. In 1938, the family moved to the Kursk region, where his father worked at the Petren Rubber Plant. In the following years, they lived in Kazakhstan, and in the Kharkiv, Stalingrad, Voronezh, and Saratov regions. After the liberation of Kharkiv from Nazi occupation in 1943, the family returned to Ukraine. Volodymyr studied in various schools, including in the villages of Andriivka, Zhovtneve, and Khotsky, ultimately graduating from secondary school with distinction in 1953 in the village of Zhuravka, Chernihiv region.

That same year, he entered the Metallurgical Faculty of the Kyiv Polytechnic Institute — a logical step for a technically gifted graduate. After completing his studies, Telnuk-Adamchuk worked at the Novokramatorsk Machine-Building Plant. However, since childhood, he had been fascinated by the stars and the universe. The launch of the first artificial satellite of the Earth in 1957 had a profound impact on him and became a turning point in his life, prompting a decisive shift toward astronomy.

In 1959, he enrolled in the correspondence department of the Faculty of Mechanics and Mathematics at Taras Shevchenko Kyiv State University. In 1962, after three years of factory work, he moved to Kyiv and met with Professor Oleksandr Fedorovych Bohorodskyi, the Director of the Astronomical Observatory. Following their interview, Telnuk-Adamchuk was accepted into the astrometric department, where he actively began his scientific career while continuing his university studies.

His contribution to science is significant: he authored more than 180 scientific papers, participated in numerous conferences, and co-authored the School Astronomical Handbook together with I. A. Klymyshyn. Thanks to his deep knowledge, dedication, and sincere passion for astronomy, he earned recognition in the scientific community and played an important role in popularizing the field among young people.

Volodymyr Telnuk-Adamchuk's life path serves as an inspiring example of how personal interest and perseverance can shape one's destiny. His journey from metallurgist to renowned astronomer is not only a story of professional transformation but also a testament to the power of curiosity and commitment to one's true calling.

Vilhelm Fredrik Fabricius, an observatory astronomer and coeval of the Astronomical Observatory of Kyiv University, and the study of some gaps in his biography

L. Kazantseva

Astronomical Museum of the Astronomical Observatory
of the Taras Shevchenko National University of Kyiv, Kyiv

Marked in documents as Vasily Ivanovich Fabricius (1845-1895) - a fairly well-known personality in astronomy. His brief biography can be found in many reference books and encyclopedias. Russians call him a Russian astronomer, Finns - a Finnish astronomer, but still he is better known as a Kyiv astronomer, because he spent the longest part of his not very long life at the Kyiv Observatory. It was while working in Kyiv that he published his famous works, was an active participant in scientific societies and the Drawing School.

He received his secondary education in Vyborg, Leipzig and Helsingfors, graduated from the course of mathematical sciences at the University of Helsingfors in 1870, and worked there as an assistant professor of astronomy at the university observatory. In 1871-1873 he held the position of assistant at the Royal Observatory in Bonn on the Rhine, in 1874-1876 he worked as a computer at the Pulkovo Observatory, and from February 1876 to 1894, until he was overcome by illness, he worked at the Observatory of the Kiev University of St. Volodymyr

Unfortunately, not much material about his life has been preserved in the Astronomical Museum of the Observatory, which could supplement his biographies written earlier. But still, among his surviving observation journals, we managed to find little-known facts. Between the lines of calculations and measurements in the 1874 notes are several handwritten pages describing his trip to what was then Persia, to the island of Ashur-Ada in the Caspian Sea, to observe the transit of Venus across the disk of the Sun. That year, he failed to observe this rare phenomenon because of weather. But the description of the trip itself, the preparation for the

observations, and other details of the journey are of interest and have never been made public.

Popular science publications on astronomy during the period of Ukrainianization (1923-1933)

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With the establishment of Soviet power in Ukraine, the Bolsheviks faced the hostile attitude of the population and were forced to make some concessions. One of them was the policy of Ukrainization, which was carried out in 1923-33. According to the organizers plan, it was to be expressed in the introduction of Ukrainian language in education, press and other spheres of cultural life. Popular science publications on astronomy were no exception.

For example, since 1923 (the beginning of Ukrainianization), more than thirty five Ukrainian brochures on astronomy have been published in various state publishing houses (DVU, Proletar, Shlyakh Osvita, etc.) and were aimed at educating the general population. The brochures were published in several series: “Library of Natural History”, "Popular Science Library. World Studies Series Mass Library. Nature and People" and others.

In terms of content, the brochures were different, among them we can single out the biographical direction - brochure “Galileo Galilei” by G. Lesnovsky (1930), which introduced readers to biography of the scientist and his achievements, and G. Gurev “Copernican heresy in past and present” (1931), which provided information about the lives of the creators of heliocentric system of the world Copernicus, Bruno and Galileo. The publications of anti-religious orientation include the brochures by B. Gerasimovich “Fairy Tales and Science of the World's Uprising” (1924), M. Zarovnyadny “Was the World Created in Six Days?” (1927), and G. Gurev “The Science of Heaven Against Christianity” (1932). The broadest area was astronomy, represented by brochures by O. Strelbytskyi “The Structure of the World and Its Secrets” (1923), B. Ostashchenko-Kudryavtsev “20 Conversations on Astronomy” (1925), L. Andrenko “Life and Death of the Heavens” (1925), B. Herasymovych's The Universe (1926), M. Barabashov's “Life, Evolution, Death and Revival of Stars” (1930), O. Laskavy's “A Journey Through the Sky” (1930), and H. Gurev's “Among the Distant Suns” (1933). These brochures, based on the variety of their

titles, provided the reader with the most up-to-date knowledge of the time in various fields of astronomy, from information on the structure of the solar system bodies to the consideration of stellar evolution and the origin of the universe. Separate consideration should be given to the brochures by H. Strashnyi "Through the Glass to the Sky" (1925) and H. Hurev "How to Study the Sky" (1933), which introduced readers to the methods of astronomical research and the operation of basic astronomical instruments of the time. As we can see, these publications were diverse in nature and aimed at the wide popularization of astronomical knowledge among the population.

However, this publication considers only some of the popular science brochures on astronomy of the time. More details will be discussed in further research.

Kyiv University Graduate Yuliy Nadubovych and the History of the Creation of a Scientific Station for the Study of the Northern Lights Beyond the Arctic Circle

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In 2024, the scientific community of cosmophysicists celebrated the 90th anniversary of their colleague Yuliy Arkadiyovych Nadubovych (1934-1991), a Ukrainian, a graduate of the Taras Shevchenko University of Kyiv, who stood at the origins of research in this field.

He, together with others, was sent from Kyiv from the Department of Astronomy of the Faculty of Physics in 1957 to the Arctic during the International Geophysical Year to participate in observations and research of the auroras, was one of those who created an observation station in Tiksi, set up equipment and began regular observations, and was also one of the first to begin analyzing them. His fate was such that in the future he continued the research he had begun and devoted his whole life to the north, working in Yakutsk and Norilsk, but maintained contact with colleagues from Kyiv.

Thanks to the case, the Astronomical Museum received some original archival materials from the scientist's family, which helped to recreate the authentic history of the life and scientific path of Yu.A. Nadubovich. On

their basis, it was also possible to investigate the history of the creation, formation and work beyond the Arctic Circle of the small town of Novokafedryansk, as it was called among itself by Kyiv graduates - participants in those events.

Personal documents of Ya. A. Nadubovich, photographs, letters, scientific publications, newspaper clippings and their copies significantly supplemented the previously available materials of the Astronomical Museum's funds and allowed us to chronologically recreate a significant event in the history of the Department of Astronomy and the Astronomical Observatory of Kyiv University – expanding the topics of scientific research, involvement in a large international scientific project, obtaining a large array of observations, creating a database of observations of the Arctic Circle, which was used by Kyiv astronomers for a long time.

In addition, we recreated the biography and memory of our fellow countryman, university graduate, scientist, student of S.K. Vsekhsvyatsky, who achieved success in research into the physics of space and near-Earth space.

The history of the families of two employees of the Astronomical Observatory of the University of St. Volodymyr: the Fabriciuses and the Goshkevychs

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Since the 1960s, the direction of the “new historical science”, or anthropologically oriented social history, has been formed in the humanities of Western Europe and the USA. It arose within the framework of the French “Annals school”, the founders of which were Marc Blok and Lucien Febvre, and structural anthropology. One of the genres of research was the “new family history”. In the last decades of the 20th century. in world historical science, the history of the family, marriage, family and kinship relations, childhood, old age became an essential aspect of historical and demographic research and social history. It makes it possible to get closer to understanding the objective, sedentary, far from rapid changes, basic structures of human and social existence. The family is the most important social institution of reproduction and socialization of new generations. As a social institution, it is not doomed to passivity, but is capable of influencing

the course of socio-historical changes through its family and demographic structure. The problem of the relationship of the family with society and its social institutions, as well as with the individual, has always existed in history and has aroused scientific interest. The history of families in Ukraine in recent decades has also been gaining increasing popularity among researchers.

Many representatives of the Fabricius and Hoshkevych families became famous as scientists, artists, politicians, and military personnel. Thanks to the astronomical observatory of St. Volodymyr University, the fates of these families were closely intertwined. Vasyl Fabricius worked here as an astronomer-observer in 1876-1894. Viktor Goshkevych also worked as a computer operator at the observatory in 1880-1883. It so happened that in 1890 he moved to Kherson with V. Fabricius's wife and three of his children. V. Goshkevych was engaged in archaeological research and founded the Kherson Historical and Archaeological Museum. Iryna Fabricius was brought up in his family. Later, she became the director of the museum. The researcher published an archaeological map of the Northern Black Sea Region, studied the Bronze Age and Scythian history. Kateryna, the granddaughter of Vasyl Fabrytsius, became a geologist.

Studying the history of these families allows us to trace the mechanisms of transmission of family traditions. This is relevant, since cultural inheritance from generation to generation is one of the important conditions for the further development of society.

Missed and Latecomer abstracts

Strong spin-gravity action in the linear approximation

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In general relativity, the effects of gravity action on a spinning particle are described by the Mathisson-Papapetrou (MP) equatins [1] for a macroscopic particle and by the general relativistic Dirac equation [2] for a quantum particle with the spin 1/2. In the linear in spin approximation, for the MP equations there is the clear correspondence between the results which follow from these equations and the quasiclassical limit of the Dirac equation. The important properties of the spin-gravity coupling appear in the trajectories of the spinning particle in the Schwarzschild field as compared to the trajectories of the spinless particles. The main factor which determines the essential spin-gravity effects is the high velocity of the spinning particle [3-5].

In general, according to the MP solutions, in the linear in spin approximation the deviation of the world lines and trajectories of a spinning particle from the corresponding geodesic lines is very small. However, another situation takes place when the spinning particles moves with highly relativistic velocity in the space region close to the Schwarzschild's radial coordinate $r=3M$. In this context, we consider some examples when the action of the spin-gravity coupling on the spinning particle is strong.

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Machine learning classification of RadioGalaxyNET dataset

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In our work, we perform the machine learning classification of galaxies in RadioGalaxyNET [1] dataset. RadioGalaxyNET is new and one of the largest datasets of radio images of galaxies. It is based on the observation of the Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope and contains 4155 instances of radio galaxies in 2800 images with both radio and infrared channels. They were identified and human-classified into 4 general known morphological classes of radio galaxies: FRI, FRII, compact, and bent/irregular. To build a viable model of machine learning classification, we perform cropping and preprocessing with morphological transformations of images (so-called "opening transformation") with the following largest-pixel-blobs selection. Then we train a convolutional neural network model and experiment with its hyperparameters to achieve the highest accuracy rate. On average, it is possible to achieve an accuracy rate of at least 0.8 in this problem, which, in the domain of automated radiomorphology classification, can be regarded as a relatively good result. The accuracy rate is higher if one uses data augmentation and/or unbiasing data sampling. We also experiment with data dimensionality reduction to improve the results.

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Exploring the Clustering of Cosmic Web

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As new generation of deep photometric galaxy surveys (e.g. The Cosmic Evolution Survey, COSMOS) start releasing huge amounts of data, application of "classical" methods of exploring the spatial clustering in Cosmic Web has become more challenging for the number of reasons.

Under the "classical" paradigm the estimation of clustering is defined as an excess of structure over the "random" distribution of points generated by spatial point process, measured in terms of 2-point correlation function. Such approach provides the benefits of clear interpretation so it's easy to connect with theoretical description of phenomenon of Cosmic Web. However, with difficulties and restrictions of real-world observational data such estimation is far from straightforward to implement at scale, and it appears to suffer from false detections and lacks robustness. Also, the basic parameters and assumptions makes the procedure less reproducible.

Here, I want to suggest other approach to characterization of clustering in observational data, based on less-parametric methods of spatial point processes statistics. Namely, these methods include measures of spatial homogeneity, like Ripley's K and Besag's $L*$ functions, as well as Lieshout-Baddeley J function. I applied these estimates to a number of datasets from COSMOS2020 data release, and they proved to be simple, robust and scalable methods for exploring observational data on Cosmic Web.

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