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"ASTRONOMY AND BEYOND: ASTROPHYSICS, COSMOLOGY AND GRAVITATION, ASTROPARTICLE PHYSICS, RADIO ASTRONOMY, ASTROBIOLOGY AND GENETICS"

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MEMORIAL SESSIONS

70 YEARS OF LOW-FREQUENCY RADIO ASTRONOMY IN UKRAINE

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Throughout the more than one-hundred-year history of the National Academy of Sciences of Ukraine, low-frequency radio astronomy has remained one of the country's priority areas of both fundamental and applied research. This field was established during the mid-1950s by the outstanding scientist Academician Semen Ya. Braude, with the unwavering support of Academician Borys Ye. Paton, President of the National Academy of Sciences of Ukraine.

Among Semen Braude's many remarkable contributions to radiophysics, geophysics, radar engineering, and applied military research, his greatest legacy is undoubtedly the creation of the Ukrainian school of low-frequency radio astronomy, together with its unique experimental facilities and internationally recognized scientific achievements.

Over the past seventy years, several generations of his colleagues, students, and successors have not only preserved this scientific heritage but have continuously expanded it through the modernization of UTR-2, URAN-1...URAN-4, and the construction of entirely new instruments such as GURT, mobile antenna arrays, and specialized systems for future ground-based and space missions.

Ukraine's independence in 1991 opened a new era of international collaboration and integration into the global radio astronomy community. The scientific achievements obtained during recent decades, particularly through international collaborations, are now widely recognized. The Ukrainian radio telescopes UTR-2, URAN, and GURT have become indispensable components of the worldwide development of low-frequency radio astronomy and have contributed significantly to the realization of next-generation facilities including LOFAR, NenuFAR, LWA, MWA, and SKA-Low.

These achievements fully justify Semen Braude's visionary decision to establish a new school of low-frequency radio astronomy in the 1950s, recognizing long before most others the extraordinary astrophysical importance of this wavelength range.

80-TH ANNIVERSARY OF GAMOW'S HYPOTHESIS ON COSMOLOGICAL NUCLEOSYNTHESIS

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In his paper Expanding Universe and the Origin of Elements, published in 1946, George Gamow developed the idea that the observed abundance of chemical elements was determined during the early stages of the expansion of the Universe. In contrast to the equilibrium interpretation of element abundances discussed at that time, Gamow proposed that primordial nucleosynthesis was a nonequilibrium process governed by the rapid expansion of the hot and dense Universe. He showed that the characteristic time scale of cosmic expansion was sufficiently short to prevent the establishment of nuclear statistical equilibrium and suggested that the primordial chemical composition was formed during this brief early epoch of cosmic expansion. The report is devoted to the physical ideas presented in this paper and their development during the subsequent eighty years. The observational tests

of Gamow's hypothesis based on the primordial abundances of light elements and the cosmic microwave background will be discussed. It will be shown which elements of the original hypothesis have been confirmed by modern cosmology, which required revision, and how they led to the present theory of Big Bang nucleosynthesis and the physical model of the early Universe.

OUTSTANDING DIRECTORS OF THE ODESA ASTRONOMICAL UNIVERSITY OBSERVATORY: TO THE 155TH ANNIVERSARY

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In 1863, Odessa City Magistrate (Duma) decided to establish an astronomical observatory in Odessa. Two years later, the Imperial Novorossiysk University was opened, along with its Department of Astronomy and Geodesy. From 1865 to 1880, it was headed by Professor L.F.Berkevich (1828-1897), a graduate of St. Petersburg University, a Master of Science and then Doctor of Astronomy. He founded the observatory, which opened in 1871, and headed it until 1880. The observatory was initially used as a base for the academic work of the Department of Astronomy and Geodesy, while also fulfilling a number of city duties: checking ships' navigational instruments, monitoring the correct operation of city clocks, and determining the timing of city lights. A street in Odessa is named after Berkevich.

The second head of the department and observatory from 1881 to 1910 was Professor A.K.Kononovich (1850-1910), who significantly expanded the observatory, equipping it with the latest scientific equipment and broadening its scientific focus, turning it into one of the largest scientific institutions in the country's universities. During these years, in addition to studying the motion of celestial bodies, the observatory began to develop astrophysical research of the Sun, planets, and stars. In historical literature, A.K.Kononovich is rightly called the first astrophysicist in the south of the country. A lane in Odessa is named after Kononovich.

A.K.Kononovich was succeeded as head of the department and observatory (1912-1934) by a young but already established professor, A.Ya.Orlov (1880-1954). He rebuilt the observatory buildings, significantly expanded the scientific scope, published a number of textbooks, and trained a large number of outstanding scientists. The outstanding 20th-century physicist and cosmologist G.A.Gamow, who was also listed as an employee of the observatory, worked under A.Ya.Orlov. Alexander Orlov created the first gravimetric map of the country, identifying many deposits, became an academician of the Academy of Sciences of the Ukrainian SSR (1939), created the Poltava Gravimetric Observatory and served as its director (1926-1934), and then served as director of the Main Astronomical Observatory of the Academy of Sciences of the Ukrainian SSR (1944-1952). Thanks to the work of A.Ya.Orlov, the observatory houses two fundamental benchmarks that determine the city's location and its geophysical characteristics. These are gravimetric and geodetic benchmarks, registered in international catalogs and protected by the state. A lane in Odessa is named after Orlov.

In 1934, the world-renowned scientist, Corresponding Member of the USSR Academy of Sciences, Professor K.D.Pokrovsky (1868-1944) became the director of the observatory. He reestablished the astronomy department at the newly opened university, which was named Odessa State University, and its graduate program. He also served as dean of the physics and mathematics department. He introduced a new scientific focus to the observatory—the study of comets and meteors. His main achievement was saving the Odessa Observatory from looting during the occupation of Odessa during World War II.

Professor V.P.Tsessevich (1907-1983), who arrived in Odessa in 1944, first headed the university's astronomy department and then the observatory. He expanded the university's scientific focus to include variable star research, asteroid photometry, artificial Earth satellite research, and a number of other fields. He established a strong telescope-making team in Odesa, producing approximately 40 telescopes with mirrors ranging in size from 30 to 100 cm. He also began work on a telescope with a 1.5-meter mirror diameter. He also founded suburban astronomical observation stations in Mayaki and Kryzhanovka. This outstanding scientist, educator, and popularizer led the opening of a planetarium (1963), actively lectured at the Znanie Society, headed the Odessa branch of the All-Union Astronomical and Geodetic Society, and trained a large group of scientists, educators, and lecturers. His scientific publications exceed 650 titles, and he supervised 40 PhD candidates. He was a Corresponding Member of the Academy of Sciences of the Ukrainian SSR (1948) and an Honored Scientist and Technician of Ukraine (1964). Thanks to the scientific work of V.P.Tsessevich and the contributions of Odessa astronomers to science, asteroid No. 2606 was named "Odessa." Asteroid 2498 Tsessevich was named after the scientist. A street in Odessa is named after Tsessevich.

110-TH BIRTH ANNIVERSARY OF THE FAMOUS ASTROPHYSICIST AND POPULARIZER OF SCIENCE I. S. SHKLOVSKY

M.I.Ryabov

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The 110th anniversary of the birth of Joseph Samuilovich Shklovsky, an outstanding astrophysicist, corresponding member of the USSR Academy of Sciences, a member of the National Academy of Sciences of the United States, the Royal Astronomical Society of England and many other academies, has been celebrated.

I.S.Shklovsky was born on July 1, 1916 in the Ukrainian town of Glukhov, Kharkov province. A specialist in the field of solar physics, radio astronomy and physics of the upper atmosphere, he is the author of nine books and more than three hundred scientific publications. I.S.Shklovsky made a fundamental contribution to the search for extraterrestrial civilizations and to most areas of modern astrophysics.

In 1953–1954 I.S.Shklovsky was the first in the USSR to teach the first fundamental course in radio astronomy. He soon expanded his course to include all-wave astronomy which was made possible by observations from spacecraft in orbit. He was one of the first to engage in radio astronomy, studied the mechanisms of radio emission from the Sun and the Galaxy, pointed out the possibility of observing interstellar molecules in the radio range and explained the radio emission of the remnants of supernova explosions.

On the basis of Gamow's theory of the "Hot Universe" Shklovsky introduced the terms "relict radiation". On the basis of his research and generalizations, the modern theory of the solar corona was created. A number of his studies are devoted to auroras and infrared radiation from the night sky.

Since the era of the first satellites Joseph Samuilovich has been associated with space research. He proposed a beautiful idea of an "artificial comet".

Shklovsky once wrote in relation to Gamow: "... In the end, only the concrete results of his work remain of the scientist. To use the football analogy, it's not the elegant feints and dribbling that really matter, it's the goals scored."

The scientific heritage of I.S.Shklovsky contains more than 300 articles in scientific journals around the world, covers almost all areas of modern astrophysics. His popular book "Universe, Life, Mind" had an interesting fate which, as reprints were reprinted, reflected the evolution of the author's views on the problem of extraterrestrial civilizations. In his opinion, there should not be many such civilizations.

Joseph Samuilovich Shklovsky was the head of a large scientific school. Many of his students are world-famous people in astrophysics.

Asteroid 1976 GN3 (2849) Shklovskij, which was discovered on April 1, 1976 at the Crimean Astrophysical Observatory of N.S.Chernykh, the Shklovsky crater on the satellite of the planet Mars Phobos with a diameter of 2 km, and a street in his homeland, in the city of Glukhov, are named after I.S.Shklovsky. Modern research in the field of all-wave astronomy is associated with issues that were of particular interest to I.S.Shklovsky:

– the early Universe and the CMB radiation;

– supermassive black holes, active galactic nuclei;

– sources of cosmic ray generation;

– supernovas and their remnants, gamma-ray bursts, pulsars;

– physics of the interstellar medium;

– evolution of stars, planetary systems;

– SETI problem.

I.S.Shklovsky actively collaborated with radio astronomers in Ukraine. On the basis of his predictions about the presence of excited carbon atoms in recombination lines of extremely low frequencies, A.A.Konovalenko, an employee of the Institute of Radio Astronomy NAS of Ukraine was the first in the world to detect their decameter radiation in outer space.

The author of the report had a chance to meet with I.S. Shklovsky several times during numerous conferences and even listened to his personal lecture on the way from Simeiz to Katsiveli on the RT-22 KrAO radio telescope. I.S.Shklovsky also came to Odessa where he was together with N.S.Kardashev and R.E.Sagdeev at the beginning of the fantastic film of the Odessa film studio "Orion's Loop". After the filming of the film all of them performed at the Odessa Astronomical Observatory with the enthusiastic participation of staff and students. Without a doubt, I.S.Shklovsky was a high authority of the era of the beginning of the scientific revolution of all-wave astronomy.

PLENARY SPEAKERS

50-TH ANNIVERSARY OF DISCOVERY OF MAGNETIC CATACLYSMIC VARIABLES – POLARS (AM HER – TYPE STARS)

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We review history and basic models of an exotic class of Magnetic Cataclysmic Variables (MCV) = AM Her type stars and related objects. In fact, all stars have non-zero magnetic fields. The difference is in a degree of influence of the magnetic fields onto structure (e.g.accretion) and corresponding evolution.

There are at least 25 physical mechanisms causing variability at time scales from seconds to billions years.

Depending on their relative impacts, the cataclysmic variables are divided into few subclasses.

6.10.1976, there was a workshop, which was devoted to only one star – AM Herculis. Despite its variability was discovered in 1923 by Max Wolf in Heidelberg, identifying it as an irregular variable with brightness ranging between magnitude 12 and 14 (AN 28.1923). For decades, the star was not very interesting, until S.Tapia has discovered its polarization – either linear, or circular, It was interpreted by an accretion structure in a magnetric vielsd of few hundred MGs. This resembles rapidly rotating pulsars discovered in 1967. However, a campaign of photometrical and spectral observations after this a discovery had shown that the rotational period of the white dwarf (derived from circular and linear polarimetry) and the orbital period (from spectroscopy) are the same.

This differs from all other previously known objects by smaller ratio of the (magnetic pressure)/pressure. Near the white dwarf, magnetic field decelerates the inner parts of the rapidly rotating inner parts of the accretion disk, which orbit a white dwarf at an lmost Kepler velocity. But the periodicity of such a signal is hidden outside by an upper accretion disk. With increasing accretion height of the accretion column, the rotational variability becomes more prominent. Historically, DQ Her was first to show such a variability (reported in 1974). Thus AM Her has become a "missing link", namely, "extremely magnetic part" of a group of cataclysmic variables.

We review polars (AM Her, QQ Vul, V808 Aur, et al, asynchrFors polars (V1432 Aql, BY Cam), intermediate polars (BG CMi, V405 Aur, MU Cam, V1323 Aql et al), magnetic white nova (DO Dra), Nova-Like stars (TT Ari, MV Lyr at al).

FROM GAMOW'S VISION TO THE MULTI-PROBE UNIVERSE

Carlo Baccigalupi
SISSA, the International School for Advanced Studies in Trieste, Italy

We trace the development of Cosmology from Gamow's pioneering vision of a hot early Universe and its relic radiation to the present era of precision, multi-probe observations. We discuss how complementary measurements connect the primordial fluctuations imprinted in the Cosmic Microwave Background to their subsequent evolution into galaxies, clusters, gravitational lensing and the cosmic web of Large Scale Structure.

The combination of cosmological probes provides a powerful means of breaking parameter degeneracies, controlling observational and astrophysical systematics, and testing physical explanations of Dark Matter, Dark Energy and the Early Universe. We review the present theoretical and observational landscape, the challenges involved in consistently combining heterogeneous data sets, and the opportunities offered by forthcoming ground and space based experiments.

THE DOUBLE NUCLEUS OF THE ANDROMEDA GALAXY: A WINDOW INTO GALACTIC NUCLEAR DYNAMICS

Elena Bannikova
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The double nucleus of the Andromeda galaxy is one of the most remarkable examples of a non-axisymmetric stellar structure around a supermassive black hole. Its two brightness peaks, P1 and P2, are generally interpreted as the signature of an eccentric nuclear stellar disc, although the origin and long-term stability of this configuration remain open questions. In this talk, I will review the main observational properties and dynamical models of the M31 nucleus and briefly discuss other galaxies with double or strongly asymmetric nuclei, including NGC 4486B. I will also consider how collective self-gravity can generate and maintain global (m=1) asymmetries in nearly Keplerian nuclear systems. In this context, I will discuss the prospects for detecting a displacement of the supermassive black hole relative to the surrounding nuclear structure. Such an observational test could help determine whether the global asymmetry is externally induced or represents an intrinsic dynamical state of a self-gravitating torus. Finally, I will extend the discussion to massive self-gravitating molecular tori in active galactic nuclei, including the asymmetric torus in NGC 613. Double stellar nuclei and asymmetric molecular tori may represent different manifestations of collective non-axisymmetric dynamics in galactic centres.

THREE DECADES OF COSMOLOGICAL GIBBS SAMPLING

Hans Kristian Kamfjord Eriksen
Institute of Theoretical Astrophysics, University of Oslo, Blindern, Oslo, Norway

During the last 30 years, detailed observations of the cosmic microwave background have revolutionized our understanding of the early Universe, to the point that the main cosmological parameters are now constrained with

sub-percent accuracy. Reaching such a spectacular precision has required many breakthroughs in instrumentation, theoretical interpretation, and statistical analysis methods. In this talk, I will review one thread of this development, focusing on so-called end-to-end data analysis as implemented through a Markov Chain Monte Carlo algorithm called Gibbs sampling. Originally proposed more than 20 years ago by Jeff Jewell and Benjamin Wandelt, this algorithm today serves as the computational engine in the Cosmoglobe analysis framework, which aims to build a single statistically coherent model of the large-scale Universe from radio to gamma-ray frequencies.

DIFFUSE LIGHT AROUND GALAXIES

Enrichetta Iodice
INAF–Astronomical Observatory of Capodimonte, Naples, Italy

Diffuse stellar light in galaxy clusters—spanning the outskirts of galaxies and the intracluster regions—encodes key information on the assembly history of both galaxies and their host environments.

In this talk, I will review the observational perspective on diffuse light around galaxies in clusters, with a focus on low surface brightness (LSB) features such as extended stellar halos, tidal streams, and intracluster light (ICL). These components provide direct evidence of hierarchical mass assembly, tidal interactions, and environmental processing.

I will discuss the main challenges associated with detecting and characterizing diffuse light, including surface brightness limits, sky subtraction systematics, and instrumental effects, and how recent advances in deep imaging surveys and data analysis techniques are pushing these limits.

Finally, I will present recent observational results on the distribution, morphology, and fraction of diffuse light in nearby clusters, and discuss their implications for models of galaxy evolution in dense environments.

I will conclude by outlining future prospects with upcoming facilities and surveys, which promise to further unveil the low surface brightness universe.

COMPACT STAR-FORMING GALAXIES AND THEIR IMPACT ON COSMIC REIONISATION AND COSMOLOGY

Y.I.Izotov
Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, Kyiv

Compact star-forming galaxies found at low-redshift include some of the most metal-poor galaxies known today, strong emission line galaxies with properties comparable to those of typical galaxies in the early Universe, and strong Lyman continuum emitting galaxies, which are key to understanding the sources of cosmic reionisation. For these reasons these galaxies are of great interest and importance both for our understanding of the first galaxies and for observational cosmology. Building on a unique sample constructed from the Sloan Digital Sky Survey (SDSS), we conducted multi-wavelength cutting-edge observations with the James Webb and Hubble Space Telescopes (JWST, HST), and other facilities, to determine the key properties of metal-poor galaxies, their interstellar medium, and ionising radiation field, measure the production and escape of ionising photons from compact star-forming galaxies, study the properties of Lyman-alpha emission and test the universality of indicators of Lyman continuum escape.

LEARNING ABOUT THE FIRST BILLION YEARS WITH THE COSMIC 21-CM SIGNAL

A. Mesinger
University of Catania, SNS, Italy

The 21-cm hyperfine line of HI is set to revolutionize studies of the first billion years, spanning the cosmic dawn of the first stars and eventual reionization of our Universe. I will discuss the potential of this probe in learning about the unknown astrophysics of the first galaxies as well as physical cosmology. Preliminary claims of a detection of the mean (sky-averaged) 21cm signal showcased its potential in constraining exotic dark matter-baryon interactions in the early Universe, although recent robust interpretation points against new physics. The true potential of the cosmic 21cm signal is in mapping out the first half of our observable Universe through HI fluctuations. Current upper limits on the 21-cm power spectrum already provide new insights into the heating of the intergalactic medium, likely caused by a new population of high mass X-ray binaries. Future detections will allow us to set the strongest available constraints on exotic heating mechanisms through dark matter decay and annihilation.

THE ALMA BAND 6V2 RECEIVER: A NEW GENERATION OF WIDEBAND MILLIMETER-WAVE RECEIVERS FOR THE ATACAMA LARGE MILLIMETER/SUBMILLIMETER ARRAY

A. Navarrini
National Radioastronomical Observatory, USA

The Atacama Large Millimeter/submillimeter Array (ALMA) is the world's largest and most sensitive observatory operating at millimeter and submillimeter wavelengths. Located at 5,000 m altitude on the Chajnantor Plateau in northern Chile, ALMA comprises 66 antennas working together as an interferometer, observing across ten frequency bands spanning 35–950 GHz. Since beginning science operations, ALMA has transformed our understanding of the cold Universe, enabling breakthroughs from the imaging of protoplanetary disks and the study of molecular astrochemistry to the detection of the first galaxies and the landmark imaging of black hole shadows.

After more than a decade of operations, ALMA is now undergoing its most significant enhancement since inception: the Wideband Sensitivity Upgrade (WSU). The WSU aims to at least double – and ultimately quadruple – the observing bandwidth of the array while simultaneously improving its sensitivity, by upgrading the receivers, the

digital electronics, and the correlator. The scientific return will be substantial: dramatically faster spectral surveys, improved continuum sensitivity, and access to a wider range of molecular transitions in a single observation.

Together with Band 2 and Band 8v2, the Band 6v2 receiver is one of the highest-priority wideband front ends of the WSU, and these receivers represent a cornerstone of the ALMA Development Roadmap to 2030. Band 6 (211–275 GHz) is ALMA's most heavily used and most scientifically productive band, accounting for more than one third of all observing time. The new Band 6v2 receiver, developed at the NRAO Central Development Laboratory, extends the radio-frequency coverage to 209–281 GHz and nearly quadruples the usable instantaneous bandwidth, while substantially lowering the receiver noise – approaching only a few times the fundamental quantum limit. These improvements rest on superconducting SIS (superconductor-insulator-superconductor) mixer technology operating at 4 K, together with new cryogenic optics, wideband intermediate-frequency components, and a redesigned low-noise local oscillator system.

In this talk, I will first give a general introduction to ALMA – its design, capabilities, and principal scientific achievements – before presenting the design and measured performance of the Band 6v2 receiver, and discussing how this new instrumentation will expand ALMA's discovery space in the coming decade.

DISTORTION OF CMB BY DARK AGES INTERGALACTIC GAS AND HALOES

Bohdan Novosyadlyj, Yurii Kulinich
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The cosmic microwave background (CMB) carries information not only about the recombination epoch but also about its subsequent propagation through the evolving baryonic medium. Measurements of its primary anisotropy and polarization have made it possible to determine the parameters of the ΛCDM cosmological model with unprecedented accuracy. However, recent JWST observations of massive luminous galaxies at redshifts $z\sim10-15$ indicate that the formation of the first cosmic structures may have been more complex than predicted by the standard model. This motivates the search for independent probes of the physical state of the baryonic medium before and during the formation of the first stars and galaxies. During the Dark Ages, the baryonic matter in the intergalactic medium and dark matter haloes consisted mainly of neutral hydrogen and helium atoms together with trace abundances of the first molecules, H_2, HD and HeH^+. Atomic and molecular transitions in this medium produce spectral distortions and additional anisotropy of the CMB. The strongest spectral features are associated with the hydrogen 21-cm line and the rotational and ro-vibrational transitions of the first molecules. We present calculations of these spectral distortions and anisotropies and discuss their sensitivity to cosmological parameters beyond the standard ΛCDM model. Particular attention is paid to the potential of these signals as probes of cosmological models and of the physics of the Dark Ages.

This work is carried out within 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 No. 0124U004029), supported by the National Research Foundation of Ukraine.

MULTISPACECRAFT OBSERVATIONS OF THE SPACE WEATHER AT MARS

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The space weather effects particularly the particle radiation environment represents a considerable health hazard for manned space missions to Mars and is of interest to the investigation of the cosmic rays propagation processes in the heliosphere. Sources of the radiation environment in Mars vicinity are the omnipresent galactic cosmic rays (GCR), sudden solar energetic particle (SEP) events and secondary radiation from the interaction of the primary cosmic rays with the spacecraft structures, Mars atmosphere and surface.

Presented are multispacecraft – Trace Gas Orbiter (TGO), Mars Odyssey, Mars Science Laboratory (MSL), etc. and multiinstrument observations of the particle radiation environment in Mars vicinity during solar cycles 24 and 25.

According the observations at Martian orbit conducted by the dosimeter Liulin-MO onboard TGO from May 2018 to June 2026, lowest dose rates for a 6-months are registered during the start of the decreasing phase, near to the maximum of solar cycle 25 – they are about 1.5-2 times less that the dose rates during the other phases of solar cycles 24 and 25. Highest dose rates are registered around the minimum of solar cycle 24.

Particular attention is drawn to the results for the radiation parameters obtained by multiple detectors located at the orbit and on the surface of Mars during the most intensive SEP events in solar cycle 25 – those in October 2021, February 2022, May 2024, and August 2025.

The recorded SEP events at Mars orbit (totally 30 until June 2026) are related to coronal mass ejections (CMEs) observed by the SOHO and STEREO-A coronagraphs. Most of these CMEs are associated with major X and M class flares. The observations of SEP fluxes at Mars orbit during the most powerful SEP events are compared to the observations in the same periods of proton fluxes measured by the GOES satellite at Earth orbit. Responsible for most of the SEP events registered both at Mars and in the GOES proton fluxes data are halo CMEs.

The results show the importance of long-term multispacecraft measurements (at least during a full solar cycle) of the space weather radiation parameters in Mars vicinity. Such measurements will provide the data necessary for the planning of future exploratory missions to the planet. The data on the observed SEP events add further details regarding the solar activity during the solar cycles.

BEYOND LAGRANGE: WHERE ARE THE FUNDAMENTAL LIMITS OF LARGE TELESCOPES?

Roberto Ragazzoni
Prezident INAF, Rome

While focal length was historically the primary design driver, aperture remains the dominant metric for characterizing telescope power. The Lagrange invariant, representing the product of aperture and solid angle, is commonly used to express a telescope's observational volume. However, the emergence of wide-field instrumentation, combined with advancements in adaptive optics and energy-sensitive detectors, necessitates a re-evaluation of this metric to accurately reflect modern telescope capabilities.

MAGNETOMETRY OF THE SOLAR CORONA

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Determining the magnetic field of the million-degree solar corona is one of the longstanding challenges in solar physics. So far, such diagnostics have been based on the polarization of visible and near-infrared forbidden lines of highly ionized species, as well as a few ultraviolet permitted lines such as hydrogen Lyman-alpha. However, a fundamental limitation is that these coronal lines can only be detected off-limb, severely restricting our ability to probe the magnetic field over the full solar disk. Unlike above lines, permitted extreme ultraviolet (EUV) lines can be observed both off-limb and on the solar disk.

We present new theoretical results on the linear polarization of permitted EUV lines and their sensitivity to the coronal magnetic field based on three-dimensional models of the solar corona.

Our findings highlight the diagnostic potential of permitted EUV lines as a new avenue for coronal magnetometry. This opens exciting prospects for future EUV polarimetric space observations aimed at unveiling the magnetic structure of the solar corona both off-limb and on the solar disk.

EXPLORING THE HIGH-ENERGY UNIVERSE: THE PRESENT AND FUTURE OF GAMMA-RAY ASTRONOMY WITH CTAO

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Gamma-ray astronomy has advanced rapidly in recent years, opening an increasingly detailed view of the most energetic phenomena in the Universe. This presentation will review the current state of the field, highlight key scientific discoveries and outstanding questions, and discuss the capabilities of present-day instruments. It will then introduce the Cherenkov Telescope Array Observatory (CTAO), provide an update on its status, and outline how this next-generation facility will shape the future of ground-based gamma-ray astronomy.

COSMOGLOBE DR1 AND DR2: GLOBAL ANALYSIS OF THE MICROWAVE AND INFRARED SKY

D. Watts
Institute of Theoretical Astrophysics at the University of Oslo, Norway

For the past forty years, all-sky maps of the sky have been used to measure emission from the Big Bang to the Milky Way. From the detection of the cosmic infrared background to the measurement of fluctuations in the cosmic microwave background, these all-sky surveys have enabled some of the most significant scientific breakthroughs in modern history. In this talk, I will give an overview of the recent results of the Cosmoglobe collaboration, which synthesizes some of these datasets to create a model of the sky from 1 GHz to 1 micron. In particular, I will discuss Cosmoglobe DR1, in which our team performed a reanalysis of the raw WMAP and Planck LFI's data, generating higher fidelity maps than were produced by either of the original scientific teams. I will also show results from Cosmoglobe DR2, in which we reanalyzed the time-ordered COBE/DIRBE infrared data jointly with Planck HFI maps and catalogs from WISE and Gaia, enabling improved measurements of the cosmic infrared background monopole.

THE SKAO OBSERVATORY: THE FUTURE OF RADIO ASTRONOMY

Filippo Zerbi (INAF, Milan)

Over the last 30 years and more, the international radioastronomical community has been conceiving, designing, and now building a radio interferometer with an unprecedented collecting area, frequency span, and spatial resolution. The SKA telescope, operated by the SKAO Intergovernmental Organization, is the result of this community effort. The SKA is not yet producing science-grade data, but a bunch of precursors and pathfinders like MeerKAT, ASKAP, LOFAR, and MWA are. The precursor data are used by the community, together with purposely tailored simulated data, to set up the mindset and the tools to exploit SKA in the future. The contribution is intended to provide with simplified access to the SKA world, describing where it comes from, where it is, and where it is expected to go once operational.

COSMOLOGY, GRAVITATION, HIGH ENERGY PHYSICS, ASTROPARTICLE PHYSICS

MINING THE DATA OF COSMOS2025 CATALOG

Apunevych S.
Astronomical Observatory of Ivan Franko National University of Lviv

About a year ago, COSMOS2025 Cosmos-Web galaxy catalog was released, containing data on photometry, morphology, photometric redshifts, and physical parameters of galaxies, based on James Webb Space Telescope deep near-infrared imaging, as well the legacy data from over decade of observations of Cosmic Evolution Survey (COSMOS) field.

The catalog brings the level of data quality to the next level in terms of high completeness, validity, accuracy and precision.

Here, I present the results of extensive Exploratory Data Analysis run against the catalog, focused on statistical distributions across many dimensions of dataset, in order to detect anomalies and biases, as well as other specific patterns and dependencies.

EFFECTIVE MAXWELL TYPE EQUATIONS FOR GRAVITATIONAL EXCITATIONS IN THE ENSOR GRAVITY SOURCE POSTULATION: DERIVATION, DIMENSIONAL ANALYSIS, AND TESTABLE PREDICTIONS

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When two electric charges move near each other, you feel a push or pull. That interaction is fully described by Maxwell's equations, the mathematical rules governing electricity and magnetism. Gravity, by contrast, is usually thought of as a purely attractive force. Yet in Einstein's General Relativity, a rotating mass produces a secondary effect—gravitomagnetism—in which spinning matter drags spacetime around with it, much like a spoon swirling honey. This frame dragging effect is extremely small, but satellites such as Gravity Probe B have confirmed its existence.

The new work asks whether (EGSP) predicts its own version of gravitomagnetism, and whether that prediction can be tested. EGSP reinterprets gravity as the behavior of a universal field, φ, which determines both the effective dimensionality of space and the local strength of gravity.

A central quantity in EGSP is the dimensionless constant $\eta = 0.0024$, which appears repeatedly across independent domains: galaxy rotation behavior, stochastic features of quantum measurements, and the damping of black hole ringdowns. In EGSP analyses, η functions as a validity threshold: natural observations at or below this value tend to align with the theory, while larger deviations typically do not.

From this structure, EGSP yields a concrete, measurable prediction. If correct, the Lense–Thirring frame dragging effect should differ from Einstein's prediction by roughly 0.24.

It transforms a conceptual analogy into a testable physical prediction, grounded in explicit equations and science. Second, it strengthens EGSP's internal coherence by showing that the same dimensionless constant $\eta = 0.0024$ governs seemingly unrelated phenomena: galaxy rotation curves, quantum random number generator statistics, black hole ringdown damping, and now the Lense Thirring frame dragging effect. Third, it gives a way to choose between theories. If a future satellite experiment measures the Lense Thirring precession with 0.1% precision and finds no deviation from Einstein's prediction, then EGSP is falsified.

TOPOLOGICAL AND ENTROPIC ANALYSIS OF GRANULAR AND COSMIC FILAMENTARY STRUCTURES USING DIGITAL IMAGES

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Filamentary structures are a common feature of both granular materials and the large-scale distribution of galaxies, despite the enormous difference in their physical scales and formation mechanisms. Identifying quantitative similarities between these systems may provide new insight into the universal principles governing complex self-organizing media.

In this work, we propose a unified methodology for comparing granular and cosmic structures based on the analysis of digitized images. The same images are investigated using two complementary approaches. First, spatial correlations are quantified through the cumulative excess entropy derived from the two-point correlation function calculated directly from pixel density distributions. Unlike conventional analyses based on catalogued galaxy coordinates, this approach enables identical processing of astronomical and granular images within a common computational framework.

Second, the extracted object centers are used to construct Delaunay graphs representing the topology of both systems. Standard graph-theoretical characteristics, including the clustering coefficient, degree distribution, shortest-path statistics, and Euler characteristic, are evaluated to quantify local connectivity and global network organization.

The principal objective of this study is to investigate whether a relationship exists between excess entropy, which characterizes the statistical order of the system, and graph-topological descriptors characterizing its connectivity. Such a comparison has not previously been performed using the same image data and provides a direct link between statistical mechanics and network theory.

The proposed methodology establishes a common quantitative framework for comparing filamentary structures in condensed matter and cosmology and may serve as a basis for future machine-learning applications aimed at the automatic classification of complex spatial patterns.

RARE, FORBIDDEN, AND EXOTIC ALPHA DECAYS

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G.Gamow was the first to develop a successful theoretical description of alpha decay, explaining the empirical observations known for this type of radioactivity. With certain modifications, Gamow's model (the tunneling of an alpha particle from the nucleus through the Coulomb barrier) remains in use today. The model has proved remarkably successful, as it provides a reasonably accurate description of lifetimes that are 10 orders of magnitude longer than the longest-lived nuclides known in 1928.

The talk will present a brief overview of recent experimental studies on alpha decays in extremely long-lived nuclei. In addition, closely related phenomena, such as cluster radioactivity and the recently predicted—but not yet observed—double alpha decay, will be discussed.

PRIMORDIAL HELIUM ABUNDANCE REDETERMINATION USING MULTICOMPONENT PHOTOIONIZATION MODELING OF HII REGIONS WITH STAR-FORMING REGION INSIDE

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We present a method for modeling H II regions around star-forming regions. In our method, we use a "bubble" structure of H II regions, which is divided into internal and external components. The internal components include the freely expanding region of the superwind and the superwind cavity, while the outer components include the gas layer compressed by the shock wave of the superwind and the hydrodynamically undisturbed outer part of the H II region. The spectrum of the Lyman continuum, mechanical luminosity, mass-loss rate, and chemical abundances of the central star-forming region are calculated using evolutionary population modeling and are used as input parameters for further photoionization modeling of H II regions. As a result of this modeling, we obtain the initial Lyman continuum spectrum, radiation fluxes at different wavelengths, and the evolutionary distributions of the electron temperature and electron density within the H II region. Using the calculated relative ionic abundances of chemical elements, we redetermine the primordial helium abundance and compare our results with those obtained by other authors.

ON THE POSSIBILITY OF STEREOSCOPIC TOMOGRAPHY OF THE EARLY UNIVERSE USING MOLECULAR HYDROGEN LINES

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Alongside the widely studied tomography of the early Universe based on the 21 cm hyperfine transition of neutral hydrogen, tomography using the rotational lines of ortho- and para-molecular hydrogen (H_2) represents a promising complementary approach. Unlike the 21 cm signal, which traces the distribution of neutral atomic hydrogen, molecular hydrogen emission is directly linked to the cooling of primordial gas and the formation of the first gravitationally bound structures. This opens new opportunities for three-dimensional mapping of the early Universe and for probing the physical conditions during the Dark Ages and Cosmic Dawn. In this work, we investigate the feasibility of such tomography using self-consistent calculations of primordial chemistry and molecular cooling in minihalos. The three-dimensional distribution of minihalos is generated with the 21cmFAST code, while the thermodynamic evolution of the gas, primordial chemical network, and molecular cooling are computed self-consistently to determine the abundance of molecular hydrogen and the populations of the ortho- and para-H_2 rotational and vibrational levels. Based on these calculations, we estimate the expected line emission and assess its potential for stereoscopic three-dimensional mapping of the early Universe.

This work is carried out within 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 No. 0124U004029), supported by the National Research Foundation of Ukraine.

TWO APPROACHES TO MODELLING SPECTRAL ENERGY DISTRIBUTIONS OF DWARF GALAXIES DURING THE COSMIC DAWN

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The spectral energy distributions (SEDs) of dwarf galaxies during the Cosmic Dawn epoch are essential for investigating the ionization and thermal evolution of the intergalactic medium, the escape of ionizing radiation, and the contribution of low-mass galaxies to cosmic reionization. Reliable modelling of these SEDs requires a self-consistent treatment of stellar populations, the

hydrodynamical evolution of the surrounding nebular gas, and radiative transfer through the baryonic component of dark matter haloes.

We present two approaches to modelling the spectral energy distributions (SEDs) of dwarf galaxies. Both approaches combine evolutionary population synthesis (EPS) calculations with hydrodynamical modelling of the nebular environment surrounding a central star-forming region. The hydrodynamical evolution of the superwind bubble is taken into account during the modelling of ionizing radiation transfer from stars through the baryonic component of the halo hosting the dwarf galaxy. This enables a physically consistent description of the evolving ionization structure and emergent radiation field.

The first approach is based on the IllustrisTNG cosmological galaxy formation simulations, which provide the physical properties of dwarf galaxies and their host haloes as input parameters for the calculations. The second approach employs observational constraints on dwarf galaxies in the Cosmic Dawn epoch together with star formation histories derived from simulations published by other authors. This strategy makes it possible to investigate galaxies spanning a broad range of physical conditions and evolutionary stages.

The resulting SEDs obtained with both approaches are compared, with particular attention paid to the ionizing part of the spectrum and to the influence of the adopted input parameters on the predicted radiation field. The advantages, limitations, and potential applications of both modelling strategies for studies of Cosmic Dawn galaxies are discussed.

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CALCULATION OF CHEMICAL REACTION RATES AND MATTER IONIZATION RATES FROM DARK MATTER ANNIHILATION IN THE DARK AGES

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Determining the thermal history and ionization state of the intergalactic medium during the Dark Ages is one of the fundamental tasks of modern cosmology and high-energy astrophysics. In this work, a comprehensive assessment of the impact of dark matter particle annihilation products on the state of baryonic matter is carried out through a systematic analysis of the chemical reaction kinetic parameters database KIDA (Kinetic Database for Astrochemistry).

Main attention is focused on the interaction processes between high-energy particles and neutral gas, in particular on the cosmic-ray ionization reactions of atoms and molecules. Based on the calculated primary differential injection spectra of electron-positron pairs produced during dark matter annihilation, the ionization rate of the medium is determined. The calculations comprehensively account for the efficiency of secondary particle energy absorption by the intergalactic medium at various redshifts, the thermally averaged annihilation cross-sections for different annihilation channels, and the corresponding spectral distributions of secondary particles.

Based on the obtained ionization rates, the rate coefficients of key ionization reactions were calculated for characteristic redshifts of the Dark Ages. A detailed analysis demonstrated high sensitivity of the chemical transformation kinetics and final reaction rates to the choice of a specific dark matter annihilation channel and dark matter mass.

The obtained values provide adequate physical parameters for solving chemical kinetics equations within the KIDA framework, allowing for a quantitative evaluation of the impact of dark matter on the thermal and ionization history of the early Universe. Furthermore, taking into account the calculated ionization rates allows for refining the efficiency of primordial molecular hydrogen formation, which governs the gas cooling rate.

ON THE ORIGIN OF SPIRAL STRUCTURES IN GALAXIES

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This work presents an original, interdisciplinary cosmological hypothesis linking quantum chromodynamics, the Ginzburg–Landau theory of phase transitions, and observational astrophysics of extragalactic structures. Although spiral galaxies make up about 70% of the observed galaxies in the local universe, the mechanism formation of spiral structures in galaxies is still unclear, despite the numerous theories that have been proposed. We argue that the “embryo” of spiral structures of galaxies formed in the Inflationary epoch of the Big Bang (BB), about 10-6 seconds after the creation of the Universe, at the critical point when the transition from quark-gluon plasma (liquid) to hadron matter (gas) took place. Approaching correlation length infinity near the critical point, according to Landau-Ginzburg theory of second type phase transitions, leads to the scale-invariance (self-similarity) i.e., fractality of the system. It is known that perfect self-similar object is logarithmic spiral. We argue that these developed logarithmic spirals are “embryos” of future spiral galaxies. Thus, spiral structures in galactic patterns may be traced back to a microsecond after the BB. Dark matter in halo and Super Massive Black holes at the center of spiral galaxies play important role in maintaining the stability of spiral structures during billions of years. We argue that B-mode politization in Cosmic Microwave Background is fingerprints of spiral structures. Observation Grand Designed galaxies in early universe by JWST, 300-400 million years after BB is big challenge of modern theory of galaxy formation. But this is in favor of our suggestion that “embryos” of spiral structures originate during a microsecond after the BB. Giant elliptical galaxies are formed by the merging of two or more spiral galaxies. Spiral galaxies losing dust and gas converts into lenticular and irregular galaxies. Thus, spiral galaxies are progenitors of other type (elliptical, lenticular and irregular) galaxies.

STATIC SPHERICALLY SYMMETRIC CONFIGURATIONS OF GENERAL RELATIVITY: QUALITATIVE PROPERTIES OF SOLUTIONS WITH N SCALAR FIELDS

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Roger Penrose's cosmic censorship hypothesis is one of the unsolved problems of classical general relativity and its modifications. It asserts that there are no "naked" singularities (NS) in the real universe. However, the status of this hypothesis remains unclear. Some counterexamples exist; some results suggest that solutions with NS may be stable. The importance of the cosmic censorship hypothesis stems from the fact that it is closely related to the predictive power of gravity theory. On the other hand, configurations with NS (if they exist) may be unique laboratories for studying the effects of "new physics" in regions with extreme gravitational fields. Another reason for studying NS is related to the "black hole mimickers" – configurations with NS that look like normal black holes. Interest in such objects has increased significantly after successful observations of the "black hole shadows" with the Event Horizon Telescope. This motivates investigation of solutions with naked singularities. Occurrence of naked singularities is typical in static configurations with scalar fields. The very first step on this way is to study static spherically symmetric (SSS) solutions. We study SSS configurations in General Relativity in presence of scalar fields described by maximally general Lagrangians. In this work we consider generalizations of earlier results on N scalar fields. In particular, we relax restrictions of earlier publications concerning monotonicity properties of the SF potentials. Sufficient conditions are formulated that guarantee global existence of regular solutions for all values of radial variable except the center (with naked singularity) under assumption of the asymptotic flatness. This means that the SSS solutions under some assumed general restrictions do not have spherical singularities. Limiting properties of the solutions at the center with naked singularity are also discussed.

PROBING COSMOLOGICAL PARAMETERS WITH TDA APPLIED TO 21cm LINE BRIGHTNESS FIELD FROM EPOCH OF REIONIZATION

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In our work, we test the possibility of restricting cosmological parameters by applying topological data analysis (TDA) to 21 cm hydrogen line brightness field from the epoch of Reionization. For this, we generate a suite of cosmological simulations with a widely used framework called 21cmfast. The comoving volume of each simulation is 300 Mpc. The considered range of redshift is from 7 to 13. In each simulation, we vary only one cosmological parameter, keeping others equal to Planck cosmology-corresponding values. We have tested the sensitivity to the Hubble parameter, dark matter density parameter, and spectral index of initial fluctuations power spectra. The TDA consists of utilizing cubical complexes of pixelized brightness fields. With their help, we compute the persistent homology of the fields and compare them with the Wasserstein distance. We build distance matrices with this tool between the different cosmology simulations, together with cosmologies of different initial conditions random seed to take into account cosmic variance. We have confirmed that TDA is capable of distinguishing different cosmologies at a high confidence level in the range 2-sigma uncertainties of current observations. Our approach allows us to define the redshift at which 21 cm line brightness field is the most informative for the cosmologist, which can help observations from this cosmological epoch in the near future.

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.

STABILITY OF SPHERICALLY SYMMETRIC RELATIVISTIC CONFIGURATIONS WITH POWER LAW SCALAR FIELD POTENTIAL

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Static spherically symmetric asymptotically flat configurations of General Relativity typically have naked singularities in presence of the minimally coupled scalar field (SF). We study the linear stability against radial perturbations in case of the power-law SF potentials. The boundary conditions at NS are formulated so as to provide the well-defined dynamics of the linearized equations. We have shown that unstable perturbations do not exist for large scalar field charges. We use the S-deformation method to show stability with respect to linear radial perturbations. Our results show that the system becomes linearly stable for sufficiently large values of 'scalar charge'.

MACROSCOPIC SYMMETRY-BREAKING EFFECTS ON THE NEUTRON-STAR RADIUS DUE TO SLOW ROTATIONS

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The macroscopic model for neutron stars (NSs) as a cold perfect fluid in equilibrium within the Tolman-Oppenhiemer-Volkoff (TOV) theory is extended to a small rotational angular momentum I around the symmetry axis. The NS surface deformation was taken into account in the leptodermic approximation $a/R \ll 1$, where a is a crust thickness and R is the NS radius. Within the linear perturbation approach, $I/M^2 \ll 1$,where M is the NS mass (c=G=1), using the two-branch Schwarzschild solution as the zeroth-order approximation, one obtains explicitly analytically the first-order GRT Kerr metric for the off-diagonal metric element Gtφ in the spherical Boyer–Lindquist outside (r>R) and Hogan inside (r<R) coordinates, in a separable form. The surface gradient-density terms are taken into account through the macroscopic energy density E(ρ) for the equation of state (EoS) within the Extended Thomas Fermi (ETF) approach adopted to a strong gravitational field.

Using a macroscopic rotational self-consistent approach we show that the relativistic moment of inertia (MI) Θ has a pole structure as function of the NS radius, $\Theta\_av/((1-\Theta\_t\varphi))$, through the statistically averaged Θ_av and time-angle gravity correlation Θ_tφ contributions. The latter appears because of the self-consistent relation of gravitational G_tφ to the angular momentum I. The MI contributions Θ_av and Θ_tφ are the sums of volume and surface components obtained through the ETF energy density E(ρ). As the MI is asymptotically divergent at certain NS radius R_rot, one obtains the constraint, R<R_rot, which is additional to the well known from the Schwarzschild gravity metric and TOV equations. We derived R_rot as function of the radius R in units of the Schwarzschild gravity parameters. For several well-known NSs, for which the mass M and radius R have been observed for enough large rotation periods, one finds a good condition $I/M^2 \ll 1$ for applicability of the linear perturbation approach.

ASTROPHYSICS 1
(nucleosynthesis, stellar atmospheres, kinematics, structure and chemical evolution of the galaxy)

THE DEPENDENCE OF RELATIVE ELEMENTAL ABUNDANCES IN STELLAR ATMOSPHERES

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The dependence of relative elemental abundances in stellar atmospheres on the second ionization potentials (hereafter SIPs) of the corresponding elements was investigated using the homogeneous abundance determinations published in the Fourth Data Release of the GALAH survey, obtained with the 3.9-m Anglo-Australian Telescope.

We selected 405,155 Population I stars with effective temperatures of 3000 K $\leq$ Teff $\leq$ 8000 K and metallicities of -0.1 $\leq$ [FeH] $\leq$ 0.5. The abundances of all 31 chemical elements available in the GALAH survey, with the sole exception of lithium, were used in the analysis.

The correlation coefficients between relative elemental abundances and second ionization potentials (hereafter CAIP) were calculated for three groups of chemical elements. The first group comprises eight elements with SIPs between 10.0 and 12.3 eV. The second group consists of 17 elements, whose SIPs range from 11.8 to 20.3 eV. The third group includes six elements with SIPs between 24.3 and 47.3 eV.

Statistically significant non-zero CAIP coefficients were found for several groups of stars, particularly those with predominantly radiative atmospheres. Two principal explanations have previously been proposed for this phenomenon. Both invoke charge-exchange reactions between hydrogen and helium ions and singly ionized heavy elements in stellar atmospheres. In these scenarios, the hydrogen and helium ions may originate either from the stellar atmosphere itself or from the accretion of interstellar or circumstellar material.

However, the full range of observed abundance -- IP correlations indicates that a more comprehensive physical theory is required, one that also incorporates the insights gained from recent space investigations in the Solar System.

LOCAL JEANS ESTIMATES OF THE MILKY WAY CIRCULAR VELOCITY BASED ON GAIA RGB STARS

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We investigate estimates of the Milky Way circular velocity obtained from the Jeans equation using red giant branch (RGB) stars as tracers. The main goal is to examine how the adopted description of the tracer density affects the reconstructed circular velocity curve.

Two approaches to the tracer density are compared. In the first, the density is represented by an analytical exponential profile, while in the second it is estimated directly from observed star counts in neighboring spatial volumes of identical geometry. The analytical model produces a smooth circular velocity curve consistent with previous studies. In contrast, the density estimated from star counts reveals systematic azimuthal variations in the local Jeans-based circular velocity estimates. Within the Galactocentric distance range of approximately 6–15 kpc, the differences between local circular velocity curves reach about 10–15 km s^{-1} depending on the azimuth.

The observed density is not interpreted as the exact underlying density distribution of RGB stars because it may still contain residual effects of the survey selection function, interstellar extinction, and population mixing. Nevertheless, the comparison demonstrates that circular velocity estimates derived from the Jeans equation are sensitive to the adopted tracer density description. These results suggest that, under conditions of incomplete and non-uniform coverage of the Galactic disk, the Jeans equation can be used not only to derive a global circular velocity curve but also to obtain local dynamical estimates that may provide valuable information on possible non-axisymmetric structures in the Galactic disk.

STRUCTURAL AND ENERGETIC CHARACTERISTICS OF FINITE-TEMPERATURE WHITE DWARFS

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The discovery of white dwarfs in the early twentieth century raised the problem of the energy sources and stability of stars in which thermonuclear reactions are absent or play only a secondary role. Fowler proposed that

the stability of white dwarfs result from the quantum-mechanical degeneracy of the electron subsystem, which occurs when the thermal energy is much smaller than the electron Fermi energy. Chandrasekhar extended this concept to high dense matter and formulated the theory of cold degenerate white dwarfs based on hydrostatic equilibrium equation.

In the Chandrasekhar model, a white dwarf consists of a completely degenerate relativistic electron gas and a static nuclear subsystem treated as a continuous medium. The model is characterized by two dimensionless parameters: the central relativistic parameter and the chemical composition parameter. Its principal predictions are the mass-radius relation and the Chandrasekhar mass limit. Despite its success, the model neglects several important physical effects, including Coulomb interactions, rotation, magnetic fields, and finite-temperature effects.

In this work, we present a finite-temperature model of low- and intermediate-mass white dwarfs based on a partially degenerate ideal electron subsystem and an ideal-gas nuclear subsystem. A reduced equation of state is derived by modeling the radial temperature distribution. The inverse problem is solved to determine the model parameters for several sequences of white dwarfs with different effective temperatures. The resulting models are applied to selected observed white dwarfs to reconstruct their radial temperature and density profiles and to estimate their cooling ages.

THE ROLE OF EARLY GLOBULAR CLUSTER DISSOLUTION IN ACCRETION PATHWAYS TO THE NUCLEAR STAR CLUSTER

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To date, two main mechanisms have been proposed for the formation and growth of nuclear star clusters (NSCs) in galaxies. The first suggests in situ star formation from gas that has migrated to the central regions from the galaxy's outskirts, while the second involves the accretion of stars from disrupted globular clusters (GCs) onto the galactic centre. However, these mechanisms are still open question. Here we investigate the accretion of GC stars on early cosmological timescales through detailed N-body simulations of theoretical GC models to assess the role of first mechanism in Milky Way. For the dynamical modelling, we used the updated parallel N-body code ϕ-GPU, including stellar evolution. We prepared three sets of GC models with different half-mass radii, each consisting of 50 full N-body GC models (150 GCs in total), and integrated these models in an external, time-variable MW-like potential. The simulations cover the time interval from −10 Gyr to −5 Gyr, enabling us to assess the rate of early stellar accretion onto the proto-NSC. We find that GC models with average orbital eccentricities of 0.4−0.5 and orbits oriented perpendicular to the galactic disc contribute most significantly to the mass of the proto-NSC formation. Accretion is especially efficient in the first billion years (Gyr) and in compact GC models with rhm=1 pc. In all sets, the dominant accreted stellar population consists of low-mass stars (≈ 0.33 $M_{\odot}$). However, the accreted mass alone is insufficient to fully account for the current NSC mass. Based on our extended set of numerical simulations, we obtained an average lower limit of mass contribution (≈ 6% from the current NSC mass) to the NSC from investigated GCs. Generally, we conclude that the GC stellar accretion channel alone might not be sufficient to ensure the present-day MW galaxy's NSC mass budget.

CHEMICALLY PECULIAR STARS IN STAR FORMING REGIONS

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The well-established class of Chemically Peculiar (CP) stars still has many unanswered questions about their origins. The origin of the strong organised magnetic fields in BpAp (CP2) and the He-weak (CP4) stars, for example, is an open problem with hypotheses ranging from fossil fields to stellar mergers. However, the most important question is Why some stars on the upper main sequence show these properties while stars with almost identical properties (Mass, temperature, surface gravity) do not. This also touches the question of pulsational properties of magnetic stars as well as the interplay between peculiarities and binarity of stars.

In the last about two decades, a handful of Pre-Main Sequence stars showing peculiarities in line with the CP2 phenomenon have been discovered, as well as some with measured magnetic fields. Recently, also more than 100 PMS CP stars and candidates have been discovered following an analysis of young stellar associations and open clusters, however they are too faint for current instruments to conduct a thorough investigation on their detailed properties.

In the talk, I will give an overview on the phenomenon and present recent results about new CP stars and candidates that have not yet reached the main sequence. These newly identified PMS CP stars provide promising targets for future observational campaigns and theoretical investigations.

CHEMICAL SIGNATURES FROM SUPER-EARTHS TO SUPERMASSIVE COMPANIONS IN THEIR HOST STARS

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We studied 55 planet-hosting stars and 12 stars without planets with [Fe/H] ranging from -0.6 to 0.3 dex using homogeneous spectral data obtained with the

SHARP echelle spectrograph with R = 115,000 at the La Silla Observatory, Chili. We examined possible chemical properties of stars hosting planets, including metallicity [Fe/H], abundances of C, O, Mg and Si along with their ratios, as well as masses and kinematic peculiarities of planets and their relationships. Our analysis yielded the following results: 1) stars with higher [Fe/H] have a higher probability to have massive planets; 2) more massive planets tend to be located in more distant orbits whilst often have more elongated orbits; 3) the dependences of C, O, Mg, Si abundances on [Fe/H] correspond to the chemical evolution; 4) the average C/O ratio (0.52 ± 0.15) is slightly lower than the solar one (0.54), the two values are compatible within 1 sigma; 5) We do no find any correlation between the planetary mass distribution and the C/O ratio of the respective stellar hosts; 6) planets with lower mass tends to be hosted by stars with higher Mg/Si ratios.

AUTOMATIC CLUSTERING OF KINEMATIC TRACERS OF SPIRAL STRUCTURES IN THE MILKY WAY BASED ON GAIA DR3 DATA

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This study explored the dependence of stellar radial velocities on galactocentric distance based on data from the Gaia Data Release 3 catalog of the Gaia space mission. The main focus was on developing software in Python for the automated analysis of the distribution of radial velocities and the clustering of kinematic tracers of the Galaxy's spiral structure. During the study, an algorithm for the automatic detection of local kinematic extrema was implemented, and tracers were clustered based on their spatial-kinematic characteristics. Radial velocity distribution profiles were constructed as a function of galactocentric distance, which allowed us to identify wave features associated with the spiral structure of the Milky Way. Based on the obtained kinematic clusters, the configuration of the Milky Way's spiral arms was reconstructed. The results are in good agreement with modern models of spiral structure and data from large astronomical surveys, confirming the logarithmic nature of the spiral arms and the characteristic values of their inclination angles. The proposed method enables automated analysis of large kinematic samples and can be used to study the structure of both the Milky Way and model spiral galaxies.

BOTTLINGER'S EQUATIONS FOR ESTIMATING THE DISTANCE TO THE GALACTIC CENTRE

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The distance from the Sun to the Galactic Centre (R_0) is a fundamental parameter for constraining the structure and dynamics of the Milky Way. Its precise determination remains challenging due to observational limitations in the inner Galaxy. Utilizing the unprecedented astrometric dataset provided by Gaia DR3, we applied Bottlinger's equations to a sample of about 13 million luminous giant stars (M_G < 4) to estimate the global Galactic kinematic parameters. These include the Galactocentric distance (R_0), the Solar peculiar velocity components (u_0, v_0, w_0), and the Galactic rotation parameters (ω_0, ω'_0, ω''_0). The stellar samples were selected using different heliocentric distance limits (R_0). Two vertical cuts ($|z| < 0.5$ and $|z| < 1.0$ kpc) were adopted to probe the influence of the thin and thick disk populations. The kinematic parameters were estimated using a nonlinear generalized least-squares (GLS) method based on the Levenberg–Marquardt algorithm with full covariance propagation and Cholesky decorrelation to account for heterogeneous observational uncertainties and correlations. To assess kinematic parameter uncertainties, Monte Carlo simulations comprising 100 realizations were performed by perturbing the observables according to the corresponding covariance matrices. Separate kinematic solutions were obtained for the samples with $|z| < 0.5$ kpc and $|z| < 1.0$ kpc, yielding $R_0 = 8.1648 \pm 0.0121$ kpc and $R_0 = 8.3348 \pm 0.0139$ kpc, respectively. Both estimates fall within the range of recent Gaia-based determinations. The methodology was also tested on Gaia-like mock catalogues, demonstrating its ability to recover the input Galactic parameters. Our findings demonstrate that Bottlinger's equations provide a robust and self-consistent framework for estimating the Galactic kinematic parameters and show that the inferred solutions depend systematically on the adopted vertical $|z|$ selection of the stellar sample.

SYNTHETIC PHOTOMETRY USING GAIA BP/RP SPECTRA

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For many applications in stellar astrophysics, it is important to obtain accurate estimates of astrophysical parameters. With the launch of the Gaia satellite, we saw an explosion of techniques to derive them. However, Kueß & Paunzen (2025, Astronomy, 4, 15) showed that, for upper main sequence stars, the parameter estimates in the different catalogues differ by up to ΔTeff = 10000K in temperature and 2 dex in surface gravity. Overall, the current situation is not satisfactory. Let us recall that empirical calibrations of stellar astrophysical parameters have existed since the introduction of photometric systems. Although they may no longer be applied, their advantages are manifold. They are well tested and based on intermediate- or narrow-band photometric systems, such as the Strömgren-Crawford, Geneva, and Vilnius systems. To access these calibrations, synthetic photometry based on the Gaia DR3 provides flux-calibrated low-resolution spectrophotometry (BP/RP spectra) that can be used. They provide data for about 200 million sources in the wavelength range from 330 to 1050 nm. From these spectra, synthetic photometry can be derived for any passband.

I present the basic techniques, the pitfalls, my efforts to recalibrate the synthetic Strömgren-Crawford photometric systems, the application of the synthetic Johnson photometric system, and the derivation of extinction values for 5491 Galactic open clusters. The

newest work presents a catalogue of 25 881 397 stars and their synthetic Geneva seven-colour photometric magnitudes.

PHOTOMETRIC OBSERVATIONS OF SEYFERT GALAXIES NGC 4151 AND NGC 3516

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This article presents the results of photometric observations of two Seyfert galaxies, NGC 4151 and NGC 3516, conducted at the Shamakhy Astrophysical Observatory named after N. Tusi (ShAO), located in the Shamakhy District of Azerbaijan. The observations were carried out as part of long-term international monitoring campaigns.

Multi-band photometric data were obtained in the B, V, Ic, and Rc filters over several years, revealing significant brightness variability in both galaxies. The results confirm the highly active nature of these galactic nuclei and provide important observational constraints on their photometric behavior across different activity states.

ULTRAVIOLET PHOTOMETRY AND REDDENING ESTIMATION OF 105 GALACTIC OPEN CLUSTERS

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The main goal of our research is to observe and analyze photometric data from unexplored Galactic open clusters in the ultraviolet (UV) wavelength region. We have gathered the available astrometric and photometric data. Using UV filters, we performed observations with the 2.15-meter telescope at the Complejo Astronómico El Leoncito (CASLEO) in Argentina and the 1.54-meter Danish Telescope (DK1.54) in Chile. Following the observations, we measured 105 cluster fields using Point Spread Function (PSF) photometry. The stars were then matched to the Gaia Data Release 3 catalogue. Then, we used our UV magnitudes and Gaia magnitudes to generate colour-colour diagrams. For each of the 105 cluster sequences, we fitted isochrones. We used the Hunt & Reffert (2023) catalogue as a guide to ascertain their membership. We define the reddening laws of all 105 observed clusters. These data can be used to create the first homogeneous census of unexplored open clusters in the Milky Way using ultraviolet photometry.

ABSTRACT DETERMINATION OF THE ATMOSPHERIC PARAMETERS OF SEVERAL A-TYPE SPECTRAL CLASS STARS (II)

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Using the model method, the fundamental parameters – effective temperatures (Teff) and surface gravities (g) – have been determined for A-type stars: HD 4058 (A5V), HD 83650 (A0V), HD 95426 (A1V), HD 95934 (A3V), HD 96124 (A1V), HD 97244 (A5V), HD 105778 (A4V), HD 109268 (A2V), HD 109536 (A7V), HD 135382 (A1V), HD 207673 (A2Ib), HD 209380.

The model method for determining the principal atmospheric parameters of stars – effective temperatures (Teff) and surface gravities (log g) of stars is based on the comparison of the observed and theoretical values of a number of spectral and photometric quantities that characterize these stars. This method is a simple and accurate method. In this study, photometric quantities were considered. The $[c_1]$, Q, and β indices were used as photometric quantities. These indices are free from the effects of absorption in the interstellar medium.

The following values of Teff and log g were obtained for the studied stars: HD 4058: Teff = 8386 K, log g=4.32; HD 83650: Teff = 10709 K, log g=4.17; HD 95934: Teff = 8344 K, log g=4.10; HD 96124: Teff = 8879 K, log g=4.76; HD 97244: Teff = 8056 K, log g=4.27; HD 105778: Teff = 8244 K, log g=3.72, HD 109268: Teff = 9697 K, log g=3.57, HD 109536: Teff = 8047 K, log g=4.51; HD 135382: Teff = 9351 K, log g=3.36; HD 207673: Teff = 10199 K, log g=2.18; HD 209380: Teff = 10327 K, log g=4.34.

DETAILED PHOTOIONIZATION ANALYSIS OF CHEMODYNAMICAL SIMULATION RESULTS FOR DWARF GALAXIES AT DIFFERENT EVOLUTIONARY STAGES

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Results of detailed multicomponent photoionization modeling for a star-forming dwarf galaxy at 100, 140, and 190 Myr are presented. The analysis reveals age-dependent changes in ionization structure, emission-line spectra, and diagnostics caused by diffuse ionizing radiation.

A SAMPLE OF SPECTRA OF ACTIVELY STAR-FORMING DWARF GALAXIES FROM THE SDSS SURVEY AND MULTICOMPONENT PHOTOIONIZATION MODELLING

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Dwarf galaxies are key objects for addressing the problem of cosmic reionization during the Cosmic Dawn epoch and for determining the primordial helium abundance. Therefore, studies of the physical processes occurring in these objects during episodes of active star formation are important not only for galaxy physics but also for cosmology. They possess unique properties and complex morphologies that may provide insight into the physical state and ionization structure of the nebular gas within their star-forming regions. These properties can be

investigated primarily through sophisticated multicomponent modelling of their emission based on chemodynamical simulations of their evolution. To identify physically adequate models, spectroscopic observations must be compared with synthetic spectra while taking into account the size and position of the observational aperture.

The Sloan Digital Sky Survey (SDSS) provides one of the largest databases of photometric and spectroscopic observations of extragalactic objects. To construct the sample, we used the MPA–JHU value-added catalogues, including the emission-line ratios [O III] λ5007/Hβ and [N II] λ6583/Hα, which form the well-known BPT diagram originally developed for classifying galaxies according to the dominant ionization source. Additional selection criteria included comparison of the observed spectral profiles with those characteristic of actively star-forming galaxies, as well as galaxy stellar masses. The final sample consists of 2,486 galaxies.

To compare the emission-line intensities predicted for synthetic apertures with the observed values, a multicomponent photoionization model of a dwarf galaxy was constructed, including a detailed treatment of diffuse ionizing radiation.

SPECTROSCOPIC STUDIES OF HOT FIELD STARS IN THE FIELD OF THE CEPHEID ZETA GEMINORUM

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Majaess et al. (2012) proposed the existence of the host open cluster in the field of the calibrator Cepheid Zeta Gem, consisting primarily of hot stars of spectral types B and A. Based on spectra obtained with the 0.81-m TCO telescope (North Carolina, USA) for 12 main-sequence stars from the list provided by Majaess et al. (2012), their radial velocities were determined, and their fundamental parameters and reddening values were estimated. It is shown that only a subset of these field stars can be considered as forming a probable open cluster around the Cepheid.

CHEMICAL PROPERTIES AND KINEMATICS OF GAS IN THE MILKY WAY TOWARDS THE PERSEUS ARM

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Interstellar absorption-line spectroscopy provides a powerful tool for studying the structure and physical properties of Galactic spiral arms. Observations of bright background stars make it possible to resolve multiple interstellar cloud components along a single line of sight and to investigate the distribution of gas within individual spiral arms. By combining the kinematic properties of the absorption components with Galactic rotation models and three-dimensional extinction maps, cloud groups can be associated with specific spiral arms, while their distances can be estimated and independently constrained. Furthermore, high-resolution absorption spectroscopy yields accurate chemical abundances, enabling studies of the chemical composition and depletion properties of the interstellar medium in different spiral arms along different lines of sight. We present the first results of our analysis for several sightlines toward bright stars probing the Local and Perseus Arms, demonstrating the potential of absorption-line observations for investigating the kinematics, distances, and chemical properties of Galactic spiral structure.

ASTROPHYSICS 2
(interacting binary systems and variable stars)

PROBING ACCRETION PROCESSES IN THE HERBIG STAR HD 141569A WITH A DEBRIS DISK

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This study reports the results of a long-term spectroscopic investigation of the Herbig star HD 141569A. The analysis is based on spectra acquired at the ShAO during 2017–2023 and archival observations obtained with the UVES spectrograph at the ESO VLT in 2007. Synthetic spectral modeling was employed to isolate the intrinsic emission component of the hydrogen lines from the underlying photospheric contribution. The reconstructed Hα–Hδ emission profiles exhibit characteristic double-peaked structures with a central depression, consistent with gas rotating in a Keplerian circumstellar disk. Using the peak separation velocities, the effective formation radii of the individual hydrogen lines were determined. An increase in the gas rotational velocity toward the inner disk regions is revealed, accompanied by a gradual decrease in the peak intensity ratio, Iv/Ir. The Na I D, Ca II K, and metallic absorption lines trace a gaseous outflow with a velocity of -13 ± 1.5 km s^{-1}. The relatively narrow widths of these features, compared to the stellar rotational velocity, suggest their origin in an optically thick stellar wind. The hydrogen lines, together with Na I D and He I λ5876, display spectroscopic signatures of ongoing accretion onto the central star. Accordingly, the mass accretion rates inferred from the Hγ and Hδ lines provide a reliable lower estimate of the actual accretion rate of HD 141569A, yielding $\dot{M}acc \approx (0.85–0.93) \times 10^{-8}$ $M_{\odot}$ yr^{-1}. The presence of weak yet persistent accretion demonstrates that, despite the evolved transitional nature of the circumstellar disk, magnetospheric transport of gas onto the stellar surface remains active.

PRELIMINARY RESULTS OF UBVRI PHOTOMETRY OF THE DWARF NOVAE ASASSN-17PM

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The cataclysmic variable ASASSN-17pm was discovered in outburst on 22 November 2017 at a brightness of V ≈ 12.5 mag. Our UBVRI photometric observations covered the interval from the discovery of the outburst until 25 December 2017.

The light curve, constructed from our observations together with AAVSO and ASAS-SN data, shows a slow decline followed by a plateau stage. On 9–10 December, the object experienced a rapid fading from 15.3 to 16.7 mag. However, about six days later the system brightened again, after which the decline resumed. The total outburst amplitude was approximately 5 mag.

Period analysis of the complete data set reveals a complex superposition of the probable orbital period (0.0597 d), manifested as a double-wave modulation, and the ordinary superhump period, averaging 0.0606 d during Stage B.

Multicolor photometry shows a systematic reddening of the system by approximately 0.2–0.3 mag during the decline. In addition, the long-term ASAS-SN light curve reveals no normal outbursts, which are characteristic of SU UMa-type dwarf novae. The presence of early superhumps, together with the absence of normal outbursts, provides strong evidence that ASASSN-17pm belongs to the WZ Sge subclass of dwarf novae.

ON THE 50TH ANNIVERSARY OF THE LOMB (1976) OVERSIMPLIFIED METHOD OF PERIODOGRAM ANALYSIS

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The paper "Least-Squares Frequency Analysis of Unequally Spaced Data" by N. R.Lomb has an extremely large number of citations (4661), according to the ADS (1976Ap&SS..39..447L). The majority of these citations partially overlap with 6603 citations of the later paper by D.J.Scargle (1982ApJ...263..835S). It looks strange, as this method is much simpler than the statistically more correct approach of the "true" least squares method published much earlier by W.Wehlau & K.C.Leung (1964ApJ...139..843W) for much more complicated method of multi-periodic oscillations. For uni-periodic uni-harmonic model (like Lomb studied), Vanisek (1969Ap%26SS...4..387V) used the "full" least squares approach with 3 parameters without voluntary fixing one of them, Further models used method of Lomb, returning to a 3-paremeter Least Squares, calling the "improved Lomb-Scargle" method. Some hirony is that the initial least squares by Karl Gauss (1815, before the Fourier (1822) transform) correctly applied to irregularly spaced astronomical data in 1964, 1969 descended in 1976, and repaired as "improved", but is used currently with the name of the supersimplified method. We show examples of fake "discoveries" from the oversimplified methods..

Data analysis, particularly of time series (dynamic series), is a fundamental method for studying measurements

of any nature—technical, natural, economic, or social. Modern spreadsheet tools (Excel, Calc, GNUmeric, etc.) and programming languages (Python, SPSS/PSPP, R, BVA, etc.) provide a wide range of statistical functions and libraries for generating colorful graphs and results, often displayed to 16 decimal places. However, such precision is frequently formal and does not correspond to the statistical accuracy of parameters, their functions, or forecasts. This paper examines popular algorithms that underpin deeper levels of data analysis. A key example is the Pythagorean theorem, which is a simplified case of the more general cosine theorem for vector sums. Oversimplification—such as assuming orthogonality of basis functions—can lead to significant distortions in accuracy and statistical significance. A practical example is the use of Excel to compute salary trends over 20 years, where formal precision masks enormous real errors in forecasting. In multivariate cases, approximations (linear combinations of basis functions with constant coefficients) require careful treatment of variance, which depends on the covariance matrix of coefficient errors in least squares estimation. Simplified formulas that ignore non-diagonal elements are valid only under strict orthogonality. Otherwise, full orthogonalization of basis functions is necessary to avoid misleading results. Many popular methods fall into the trap of removing the mean or trend without proper orthogonalization, leading to shifts that may range from modest percentages to several-fold errors. A prominent example is the search for signal periods using sinusoidal approximations, where orthogonality conditions are critical. The discrete Fourier transform, proposed by Gauss in 1815, ensures orthogonality under specific conditions. The Lomb method (1976), celebrating its 50th anniversary, extended these principles to unevenly spaced data, becoming a cornerstone of modern spectral analysis. Statistically optimal forecasting algorithms are taught in the PhD-level course “Methods of Scientific Research and Experimental Planning.” Algorithms for multi-harmonic and multi-periodic signal analysis, originally implemented in Fortran, have been further developed in the MCV (Multi-Column View, http://uavso.org.ua/mcv/MCV.zip) program with graphical interfaces. Detailed reviews, including the anniversary of Lomb’s method, are provided in refererd works. This abstract highlights the risks of oversimplified models, the necessity of orthogonalization, and the enduring relevance of Lomb’s contribution to periodogram analysis. More detailed review is on 2020kdbd.book..191A.

THE NEW FLARING STAR GAIA DR3 28446770992650624

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In 2016, flaring activity of the star Gaia DR3 28446770992650624 was discovered serendipitously at the Chuhuiv Observational Station of the Research Institute of Astronomy, V. N. Karazin Kharkiv National University. The observations were obtained during a single night with the 0.7-m AZT-8 reflector in the Johnson–Cousins R photometric band. During the flare, the star brightened by 3.9 magnitudes. Within two minutes, its brightness increased from 19.2 to 15.3 mag, followed by a gradual decline to 18.7 mag over the next two hours.

Photometric color indices for the star were obtained from the VizieR database using Pan-STARRS (g-r; r-i; i-z), 2MASS (J-H; H-K), and WISE (w1−w2) catalogs. In addition, the star's spectral energy distribution (SED) was constructed. These data indicate that the star belongs to the M5–M6 spectral type.

We conducted a search for additional flaring events and identified three more flares with amplitudes ranging from 1.5 to 3.0 mag in the ATLAS and ZTF survey databases.

We are conducting observations with the Liverpool Telescope to search for low- and moderate-amplitude flares.

SPIN PERIOD VARIATIONS OF THE WHITE DWARF IN THE INTERMEDIATE POLARS V405 AUR, V2069 CYG, RX J2133.7+5107

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Study of the structure and evolution of magnetic cataclysmic binary stars is an actual problem of the modern astrophysics. Intermediate polars are close binary systems which consists of a compact object – a white dwarf, and a red dwarf filling its Roche Lobe. Such systems are physical laboratories that enable study of the influence of magnetic field on flows of matter.

We run photometric monitoring of the intermediate polars since 2007. In recent years, obtaining new photometric data has been difficult due to restrictions on crossing the state border imposed by the authorities. We analyzed the latest AAVSO data (obtained in 2024-2026) in conjunction with the previous data sets and obtained following results.

The (O-C) diagram of V405 Aur shows spin period increase (spin-down) since the beginning of 2015 and latest data confirms it. The current value of the spin period is 545.456268(3) s. $\dot{P} = 5.67(5) \times 10^{-12}$ suggests that the spin period increases on a characteristic time-scale $P_\omega/\dot{P}_\omega = 3.05(3) \times 10^6$ yr. We have not found any earlier publications of the value of this parameter, so it is defined for the first time for this object.

The (O-C) diagram of V2069 Cyg since 2014 shows white dwarf spin period decrease and the best fits to (O-C) diagram is parabolic. Insufficient data for the previous seasons did not allow us to make a continuous unambiguous cycle counting since 2007. The data between 2014 and 2024 correspond to the current value of the spin period of P = 743.39449(4) s. The white dwarf in V2069 Cyg shows a spin-up with $\dot{P} = -6.29(7) \times 10^{-11}$ and a characteristic time of $3.75(4) \times 10^5$ yr. This is close to values presented last year but has around 2 times better accuracy estimate.

The (O-C) diagram of RX J2133.7+5107 shows spin-up of the white dwarf and this object has one of the fastest spin-

up timescales of all known intermediate polars. Including data for two recent years, we report the value of the spin period of 570.809192(5) s, $\dot{P} = -1.2190(7) \times 10^{-10}$$ and a characteristic time of $1.4839(9) \times 10^5$ yr. These values are consistent with our previously published paper.

Period variations detectable at a time scale of decades are frequently observed in intermediate polars and may be caused by changes of the accretion rate due to modulation of the mass transfer caused by magnetic activity of the red secondary fluctuations of the orbital separation, or precession of the magnetic white dwarf (which will be present either with constant, or variable accretion rate).

REVISITING γ CASSIOPEIAE WITH AN EXTENDED SPECTROSCOPIC DATABASE AND REFINED METHODOLOGY

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Gamma Cassiopeiae is the prototype of a class of rapidly rotating Be stars characterized by persistent, unusually hard X-ray emission. For decades, the origin of this emission remained controversial, with competing scenarios invoking either magnetic interaction between the star and its decretion disk or accretion onto an unseen compact companion. Although previous optical studies revealed a radial-velocity period near 203.5 days, uncertainties in orbital eccentricity, instrumental systematics, and companion nature prevented a definitive interpretation.

We present a thirteen-year optical spectroscopic study of γ Cas based on 249 Hα spectra obtained between 2013 and 2026. The dataset combines dedicated observations acquired with the Shelyak eShel échelle spectrograph (R ≈ 12,000) at Three College Observatory, North Carolina, USA, and archival spectra retrieved from the Be Star Spectra database. Radial velocities were measured using a weighted mirror-profile technique applied at multiple intensity levels across the Hα emission profile.

The Lomb-Scargle periodogram reveals a highly significant signal near 204.5 days. A Bayesian MCMC fit, including a secular trend and an additional jitter term for heterogeneous instrumental precision, yields P = 202.6 +/- 0.7 days and K1 = 3.95 +/- 0.31 km s−1. A circular orbit is strongly preferred over an eccentric solution, with delBIC = 20.4. The derived mass function, f(m) = 0.00123 +/- 0.00030 Msun, is consistent with the recently confirmed 0.93 Msun white-dwarf companion and an orbital inclination comparable to interferometric disk estimates.

The Hα equivalent-width evolution further reveals long-term restructuring of the circumstellar disk, including a minimum in 2019-2021 and renewed strengthening after 2023. These results provide an independent confirmation of the γ Cas binary orbit and establish a robust framework for separating orbital motion from disk-driven variability.

AN ANALYSIS OF CHANGES IN THE LIGHT CURVES OF THE STAR FI SGE BASED ON OBSERVATIONS FROM THE TESS TELESCOPE

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We present the results of the light curve analysis for the pulsating variable star FI Sge (RR Lyrae type). The study is based on high-precision photometric data obtained by the TESS space telescope in 2024 within its RI passband with an exposure time of 200 seconds. The total observation span within the BJD 2460506.57–2460533.11 interval was 26.5 days, allowing investigation of 46 maxima and 43 minima in the light curve. The analysis revealed a complex modulation of the extrema with an amplitude of approximately 0.1 mag. Variations in the light curve shape indicate the presence of bi-cyclicity and secondary bi-cyclicity phenomena in the star. The division of pulsation cycles into four representative groups allowed us to study the light curve dynamics. We believe that the observed variations in the maxima and minima are due to the presence of at least four distinct successive pulsation cycles in the star FI Sge.

ARTIFICIAL INTELLIGENCE FOR RESIDUAL ANALYSIS AND PHYSICAL INTERPRETATION OF VARIABLE STAR LIGHT CURVES

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This work investigates the use of a large language model as an intelligent research assistant for extending the analysis of variable-star light curves beyond conventional phenomenological modeling.

The proposed approach does not replace established astronomical methods but complements them. After reproducing the published phenomenological model of a variable star, AI is employed to automate the analysis of residuals between observations and the fitted light curve. The workflow includes the identification of systematic structures in the residuals, searches for additional periodicities, phase-dependent residual analysis, correlation studies, and statistical characterization of deviations from the model. The residual patterns are used to formulate and prioritize testable physical hypotheses. The subsequent analysis will compare alternative physical scenarios capable of producing the detected residual structures, including additional pulsation modes, amplitude or phase modulation, and weak nonlinear mode interaction. Candidate models will be evaluated by their ability to reproduce both the observed light curve and the statistical properties of the residuals, providing an objective basis for selecting the most plausible physical interpretation.

The study also evaluates the capabilities and limitations of AI in this context. AI can reliably assist in data preparation, implementation of analysis algorithms,

visualization, comparison of alternative models, and generation of reproducible computational workflows.

As a test study, the methodology is applied to a previously investigated pulsating variable star. The preliminary objective is not to confirm a particular physical model but to determine whether the residuals contain statistically significant structures that may indicate additional pulsation modes, nonlinear effects, or long-term evolutionary processes. This human–AI collaborative framework provides a practical strategy for accelerating astrophysical research while maintaining scientific rigor and reproducibility.

ARTIFICIAL INTELLIGENCE AS A RESEARCH ASSISTANT IN VARIABLE STAR ANALYSIS: CAPABILITIES, LIMITATIONS, AND HUMAN VALIDATION

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Artificial intelligence (AI) is becoming an increasingly important tool in astronomical data analysis. This work explores the practical role of a large language model as an intelligent research assistant during the study of variable stars using long-term photometric surveys such as ASAS-SN. The study evaluates which stages of the research process can be reliably automated and which still require expert validation. AI is capable of assisting with target selection, preparation and cleaning of observational data, detection of outliers, construction of light curves, implementation of period-search algorithms, visualization of results, comparison with astronomical catalogs, generation of reproducible analysis scripts, and preparation of scientific documentation. The system can also explain methodological choices, compare different period-search techniques, identify potential aliases, and suggest additional analyses for multiperiodic or irregular variables. At the same time, this work emphasizes the current limitations of AI. Although the model can estimate candidate periods and interpret their significance, it cannot independently guarantee the physical correctness of the results without numerical verification and expert review. For high-confidence period determination, especially for semi-regular and irregular variables, dedicated astronomical methods remain essential. In particular, approaches developed by I. L. Andronov—including trigonometric polynomial fitting, Running Sines, scalegram, and wavelet analysis—provide rigorous statistical validation that complements AI-assisted preliminary analysis. The proposed workflow combines the efficiency of AI with established astronomical techniques. AI substantially reduces the time required for data preparation, software development, visualization, and interpretation, allowing researchers to concentrate on scientific validation and physical interpretation. Such human–AI collaboration represents a practical framework for future astronomical research, where artificial intelligence enhances productivity while the final scientific conclusions remain under the responsibility of the researcher.

TOWARD A COMPREHENSIVE O-C DIAGRAM OF SV VULPECULAE: 136 YEARS OF PHOTOMETRIC OBSERVATIONS

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Cepheid variables are luminous pulsating supergiants that play a key role in stellar astrophysics and the cosmological distance scale. Their periods are not constant – distinguishing long-term evolutionary trends from cycle-to-cycle irregularities requires construction of accurate O-C diagrams. In this work, we focus on SV Vul, one of the best-observed long-period Cepheids, with a photometric record spanning over 136 years that provides a unique opportunity to investigate long-term period variability through O-C analysis.

For this analysis we compiled photometric data from modern observational missions as well as archival sources, applying careful quality filtering to account for heterogeneity between observers and instruments. We developed a Python pipeline for O-C diagram construction based on Fourier decomposition of the phased light curve. A reference light curve shape was derived from the most representative dataset, then fitted to each source and to individual time intervals within it, allowing for phase shifts and magnitude offsets specific to each subset. The moment at which the mean-light level is crossed on the rising branch was adopted as the observed epoch O.

The pipeline has been applied to a subset of the compiled data, yielding preliminary O-C points consistent with the expected timescale of period evolution. The full analysis, including the period change rate derived from the complete 136-year baseline, will be presented at the conference.

TESS AND GROUND-BASED BVR-PHOTOMETRY OF THE ECLIPSING BINARY V405 CEP

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The eclipsing binary V405 Cep was investigated using high-precision TESS photometry together with ground-based CCD observations in the BVR bands. The combined data set provides both accurate light curves and an extended time baseline for studying the orbital period.

Times of minima were determined using the Wall-Supported Parabola (WSP) and Wall-Supported Line (WSL) methods, while the mean phased light curve was approximated with the New Algol Variable (NAV) algorithm. Published minima, TESS observations, and our new CCD measurements were combined to construct an updated O–C diagram and to investigate the accuracy and long-term stability of the orbital period.

The multicolour BVR observations also provide an independent test of the physical model previously proposed for this system. Synthetic light curves calculated with the PHOEBE software package will be compared with the observed TESS and BVR photometry to evaluate

the consistency of the published model and to identify possible refinements of the system parameters.

This study demonstrates the advantages of combining continuous space-based photometry with multicolour ground-based observations for improving orbital ephemerides and testing physical models of eclipsing binary systems.

O–C VARIATIONS OF V724 AQL FROM OBSERVATIONS AT THE KALINENKOV ASTRONOMICAL OBSERVATORY AND THE TESS ARCHIVE DATA

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We present the results of an analysis of light curves and O–C variations in the times of minima for the eclipsing CBS V724 Aql. The analysis is based on historical data, observations conducted at the Kalinenkov Astronomical Observatory during the 2015 and 2018 seasons, as well as on archival data from the TESS mission spanning the 2022 and 2024 seasons. Our observations were carried out as part of the variable-star monitoring program at the Kalinenkov Astronomical Observatory using a 70-cm telescope equipped with an SBIG ST-7 CCD camera in an instrumental photometric system approximating the standard VRI bands. Historical times of minima retrieved from databases such as the Krakow Ephemeris Guide, the Czech Astronomical Society O–C Gateway, and others, combined with 7 new times of minima obtained at the Kalinenkov Astronomical Observatory, hint at a period variation possibly attributable to apsidal motion. The 2022 and 2024 TESS archival data allow us to test this hypothesis. The results are discussed.

REFINING EFFECTIVE TEMPERATURES OF BA SUPERGIANTS

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The effective temperature is one of the key fundamental parameters of BA-type supergiants, as it directly affects the determination of their luminosities, radii, surface gravities, and evolutionary status. However, its derivation remains method-dependent and is influenced by the adopted diagnostics, photometric coverage, spectral resolution, and assumptions of stellar atmosphere models.

In this work, effective temperatures of BA supergiants were determined using three complementary approaches: spectral energy distribution fitting based on multiwavelength catalogue photometry and Castelli-Kurucz LTE model atmospheres, comparison of observed and synthetic spectra, and empirical temperature calibrations developed by our research team. These calibrations are based on optical spectral-line diagnostics and were constructed specifically for BA-type supergiants, providing an independent observational temperature scale.

The temperature estimates obtained from the three methods were compared to assess their consistency and to define adopted effective temperatures for the sample. This comparison is particularly important because commonly used temperature diagnostics rely, directly or indirectly, on stellar atmosphere models, whose applicability to low-gravity BA supergiants must be tested. The SED-based approach is especially valuable when only catalogue photometry is available or when detailed atmospheric modelling is not feasible, but it requires validation against spectroscopic indicators.

By combining photometric, spectroscopic, and empirical diagnostics, we evaluate the reliability of practical temperature-determination methods for BA supergiants and establish a homogeneous temperature scale for further determination of their fundamental stellar parameters.

SIX NEW VARIABLE STARS DISCOVERED FROM GROUND-BASED PHOTOMETRY AND CHARACTERIZED WITH TESS DATA

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We report the discovery of six new variable stars identified through an exploratory analysis of several sky fields observed by the author using a small telescope and a CMOS camera. The search employed simultaneous photometry of hundreds of objects with AstroImageJ, supplemented by custom Python-based tools developed by the author to generate aperture lists and visualize light curves across the full field of view. The variables were further characterized using TESS data, and their properties are presented. We also describe the data analysis workflow, including the software packages LCV and VS-fit, developed by the author for periodogram analysis and light-curve modelling.

V405 DRACONIS REVISITED: A THIRD COMPONENT AND NON-LINEAR O-C TRENDS

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We present an analysis of recent observations of the close eclipsing binary V405 Draconis obtained from the AAVSO International Database. Times of the flat-bottomed eclipse minima were determined using the MAVKA software, which fits an optimal model to the light curve near each minimum. Our previous analysis of the star's O-C diagram, combining our own observations with TESS data and data from several legacy surveys, indicated the presence of a third component in the system -- most likely a red dwarf orbiting the close binary pair on a circular orbit. Using the new data, we have refined the orbital parameters of this third component with our own open-source time-series analysis programs, written in FreePascal/Lazarus and

Python. In addition to the periodic perturbations in the O-C diagram, we also detect a non-linear trend that cannot be explained by a monotonic period change of the main binary. Possible causes of this behavior are discussed.

PHOTOMETRIC OBSERVATIONS OF SUPEROUTBURSTS IN THE DWARF NOVAE GAIA24AMV, GAIA19ATI, AND GAIA16ADJ

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SU UMa-type dwarf novae are a subclass of cataclysmic variable stars consisting of a white dwarf accreting matter from a late-type companion through an accretion disk. In addition to normal outbursts, these systems exhibit longer and brighter superoutbursts accompanied by periodic brightness variations known as superhumps.

We present the results of the photometric observations of three SU UMa-type dwarf novae: Gaia24amv, Gaia16adj, and Gaia19ati, obtained during their summer 2026 superoutbursts.

The long-term light curves from the BH-TOM database were used to identify the outburst state and plan follow-up observations. Continuous time-series photometry obtained during the superoutbursts revealed clear superhump modulations in all three systems. The superhump periods were determined from the combined photometric data using the Lomb–Scargle periodogram.

Observations of Gaia24amv carried out with the 0.7-m f/4 AZT-8 telescope at the Lisnyky Observational Station of Taras Shevchenko National University of Kyiv detected superhumps with a period of 0.091(3) d and an amplitude of 0.3 mag.

For Gaia19ati, time-series photometry obtained with the 40-cm f/6.8 ODK telescope at Franz-Josef Hambsch's Remote Observatory Atacama Desert (ROAD, Chile) revealed superhumps with a period of 0.076(1) d and a peak-to-peak amplitude of 0.3 mag.

For Gaia16adj, photometric observations obtained with the 0.4-m Las Cumbres Observatory telescope at the South African Astronomical Observatory (SAAO) revealed superhumps with a period of 0.086(4) d and an amplitude of 0.2 mag.

The observed superoutburst characteristics and the detection of superhumps provide strong evidence for the classification of Gaia24amv, Gaia19ati, and Gaia16adj as SU UMa-type dwarf novae.

SHORT-TERM PHOTOMETRIC VARIABILITY OF THE MASSIVE X-RAY BINARY HD 226868

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HD 226868 (= Cyg X-1) is one of the best-known and earliest confirmed stellar-mass black hole candidates. Owing to its persistent X-ray emission and optical variability, the system has been extensively studied and serves as an important target for photometric investigations. One of its defining characteristics is the presence of multiple periodic variations, including both short- and long-term periodicities. To investigate the short-term optical variability of HD 226868, we analyzed high-precision V-band photometric observations obtained from the American Association of Variable Star Observers (AAVSO) database. The data cover the period from August to September 2018. A time-series analysis revealed the presence of short-term photometric variability on timescales significantly shorter than the orbital period of the binary system. The detected brightness fluctuations indicate that the optical emission of HD 226868 exhibits intrinsic variability over short timescales. These variations are likely associated with physical processes occurring within the binary system, such as instabilities in the accretion flow, interactions between the stellar wind and the accretion disk, or other dynamical phenomena, although further investigation is required to establish their origin. The obtained results provide additional observational constraints and contribute to a better understanding of the physical nature and variability of HD 226868.

INVESTIGATING THE BINARITY OF THE Be STARS 12 VUL, β PSC, AND PZ GEM USING OPTICAL SPECTROSCOPY

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Be stars are rapidly rotating B-type stars surrounded by gaseous circumstellar disks responsible for the emission features observed in their spectra. The mechanisms governing the formation and evolution of these disks remain uncertain, and binarity is considered one of the possible factors influencing the Be phenomenon.

This study investigates possible signatures of binarity in three Be stars: 12 Vul, β Psc, and PZ Gem. The analysis is based on multi-epoch medium-resolution optical spectra (R ~ 12,000), with particular attention given to the Hα emission line as a diagnostic of circumstellar disk variability.

Radial-velocity measurements, together with variations in the equivalent width and V/R ratio of the Hα profile, are used to search for periodic changes. The periods obtained from different spectroscopic diagnostics are compared to assess whether the observed variability may be associated with orbital motion or with intrinsic processes in the circumstellar disk.

The results provide additional constraints on the possible binary nature of the selected stars and contribute to understanding the role of binarity in the activity of Be stars.

EXTRAGALACTIC ASTRONOMY AND ASTROINFORMATICS

SIMULATION OF LOW-FREQUENCY STOCHASTIC GRAVITATIONAL-WAVE BACKGROUND FOR GAIA DR3 QSO OBJECTS

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The search for gravitational waves (GWs) at nanohertz frequencies provides a unique opportunity to probe supermassive black-hole binaries, the early Universe, and cosmological processes inaccessible to ground-based detectors. High-precision astrometry complements pulsar timing arrays (PTAs) by measuring correlated proper-motion patterns induced by gravitational waves. We present realistic simulations of the astrometric response of Gaia DR3 quasars to a stochastic low-frequency stochastic gravitational-wave background (SGWB). The simulations incorporate the actual sky distribution, proper-motion uncertainties, and full covariance information of the Gaia DR3 QSO catalogue, providing a realistic assessment of the expected GW signal. Two complementary analysis techniques are investigated: Vector Spherical Harmonics (VSH) decomposition and the Hellings–Downs angular correlation (HDC) method. Extensive Monte Carlo simulations are performed using the complete Gaia DR3 catalogue of 1.6 million quasars, representing the first HDC analysis at this scale. We introduce a covariance-based weighting scheme that increases the HDC sensitivity by approximately an order of magnitude. We also investigate the effects of non-uniform sky coverage, anisotropic uncertainties, and quasar-selection criteria. The VSH method is more robust against uneven sky sampling and anisotropic noise, whereas the HDC approach achieves higher statistical sensitivity under idealized conditions, albeit at a substantially greater computational cost. We find that stringent selection based on observed proper motions systematically underestimates the recovered GW strain. For Gaia DR3, the expected detection threshold is a characteristic GW strain of approximately 10^{-11} for frequencies below ~5.6 nHz. The longer observational baselines of Gaia DR4 (66 months) and Gaia DR5 (126 months) are expected to improve the sensitivity to ~3x10^{-12} and ~10^{-12}, respectively, while reducing the upper frequency limit to ~2.9 and ~1.5 nHz, assuming the same number of quasars as in Gaia DR3.

ASTROMETRIC RESEARCH AT UKRAINIAN OBSERVATORIES: ITS ORIGINS AND TRANSFORMATION

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The article examines the principal directions of astrometric research in Ukraine, their origins, and subsequent transformation. Astronomy, one of the oldest natural sciences, emerged in response to the practical needs of humankind and has profoundly influenced the development of our worldview, technologies, and other spheres of human activity. Prehistoric astronomical knowledge has survived in archaeological monuments and ethnographic evidence studied within the field of archaeoastronomy. The formation of ideas about the Universe and the motions of celestial bodies is traced through an analysis of archaeological findings dating back to the Palaeolithic period. The article also considers the development of knowledge about astronomical phenomena recorded in chronicles and the dissemination of astronomical knowledge in Ukraine by Yurii Drohobych, representatives of the Ostroh Academy—Jan Latosz and Andrii Rymsha—and scholars of the Kyiv-Mohyla Academy, including Feofan Prokopovych and Irynei Falkivskyi.The steadily growing practical importance of astronomical research led to the establishment of astronomical observatories in Ukraine during the nineteenth century: in Mykolaiv (1821), Kyiv (1845), Odesa (1871), and Kharkiv (1888). Until the end of the nineteenth century, their scientific activities were predominantly astrometric. The article also discusses the work of the Astronomical Observatory of Lviv University, founded in 1771, which resumed its scientific activities in the nineteenth century after a prolonged interruption.

The development of astrometric research in Ukraine was inseparably connected with contemporary international studies. The nineteenth century marked the beginning of the integration of research conducted at Ukrainian observatories into global astronomy. The compilation of fundamental stellar catalogues at these observatories provided an essential basis for constructing the celestial reference frame, particularly within the scientific traditions established by A. Auwers, B. and L. Boss, and S. Newcomb. The principal astrometric programmes carried out at Ukrainian observatories during this period are analysed. A new stage in the development of astronomy began with the advent of the space age and the introduction of new observational technologies, particularly observations in the ultraviolet, infrared, and radio domains of the electromagnetic spectrum. At the beginning of the twentieth century, a long-term programme for the development of astrometry was formulated. It comprised three principal objectives: the construction of an inertial reference frame; the determination of zero-point corrections to the established

coordinate system based on observations of the major planets, together with refinement of the precession constant; and the establishment of a system of astronomical constants. This programme continued to be implemented almost until the end of the twentieth century. This period was characterised by the active development of astronomical centres, the expansion of research areas within astronomical institutions, increasing cooperation among them, and the formation of astronomical research schools led by such prominent scientists as O. Ya. Orlov, G. A. Shajn, A. B. Severny, A. O. Yakovkin, S. K. Vsekhsviatskyi, V. P. Tsesevich, O. F. Bohorodskyi, and others. The article analyses the main directions of astrometric research pursued by the scientific schools of the Main Astronomical Observatory of the National Academy of Sciences of Ukraine and reconstructs their academic genealogies or "scientific trees". Information about the principal astrometric programmes of this period—including VEGA, RaProg, Planetary Patrol, MEGA, ORBITA, FON, and KSZ—is systematised.

In the twenty-first century, advances in computing and observational technologies have enabled the construction of high-precision stellar catalogues containing more than one billion objects. This breakthrough was made possible by major space astrometry missions, particularly *Hipparcos* (ESA, catalogue released in 1997) and *Gaia* (ESA, launched in 2013).

A COOL-CORE CLUSTER, ABELL 2107, WITH NO SIGNATURE OF COOLING GAS

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The hot atmospheres of cool-core clusters should cool and condense into molecular clouds at rates of 100-1000 solar mass per year. However, molecular clouds and star formation are observed at a small fraction of their expected masses and rates. The cooling deficit is likely offset by mechanical heating by the central galaxy's radio source. Heating and cooling are maintained near equilibrium by a self-regulating feedback loop. Understanding the conditions under which thermally unstable cooling occurs is a critical aspect of maintaining a feedback loop. This question underlies our modern understanding of galaxy formation. Stellar masses of galaxies more massive than the Milky Way are thought to be limited by AGN feedback. Several central cluster galaxies whose central cooling times lie below ~ 109 yr are devoid of bright nebular emission and ongoing star formation. These galaxies all have similar tc/tff profiles to those which do contain bright nebular emission, molecular gas reservoirs exceeding 10^9 solar mass, and star formation at rates of tens of Solar masses per year. These systems spoil the correlation between low central cooling time and the prevalence of star formation, suggesting additional physics or an additional condition must be met to stimulate thermally-unstable cooling. A2107 is one of them and here we present our results based on new Chandra observations.

FAST DIFFUSE IONIZING RADIATION TRANSFER CALCULATIONS WITH THE DIFFRAY CODE

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Calculations of diffuse ionizing radiation in morphologically complex nebulae are computationally expensive, partly because the celestial-sphere grid used for angular sampling must be repeatedly generated and refined. We present DiffRay Fast, an accelerated implementation of the DiffRay code that caches the granulation grid between global iterations. We compare the original implementation with three optimisation strategies: single-time caching, cumulative refinement, and periodic regranulation. The cumulative approach proved to be inefficient because both the number of local iterations and the execution time increased as the calculation progressed. Single-time caching yielded a speed-up of 5.2 per cent relative to the original implementation, whereas periodic regranulation was, on average, a further 3.1 per cent faster and was therefore adopted. The performance of the periodic approach depends on the evolution of the granulation grid: speed-ups of 8.9–10.6 per cent were obtained for a stable grid, −7.6 to 3.8 per cent when the required precision increased rapidly, and 4.8–9.5 per cent when the grid underwent small angular shifts. Application to a realistic photoionisation model analysed in this study produced a speed-up of 13 per cent. These results demonstrate that periodic grid caching provides an effective way to reduce the computational overhead of diffuse-radiation calculations while preserving the ability to adapt the angular grid during iterative photoionisation modelling.

NEW RESULTS OF THE INVESTIGATION OF THE GALACTIC ALIGNMENT IN STRUCTURES

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At first, I present the method of the analysis the orientation of galaxies. The two main methods of the investigation of the galaxy alignment are proposed in this research. They are the analysis of the distribution of position angles of the galaxy major axes, as well as two angles describing the spatial orientation of galaxy plane that give information about orientation of galaxies in space and galaxy angular momenta. Such investigation gives us a standard test of the scenarios of galaxies formation because various scenarios make different predictions concerning orientation of galaxies in structures, distribution of spins of galaxies and alignment between the brightest galaxy and the major axis of the structure. The new version of the method makes it possible to carry out such an analysis also in the case of the absence of information on galaxies' morphological types that happens in most of the astronomical data available today. In present work, I particularly analyze the relationship between the alignment

of galaxies in structures and the structures' size and compare results obtained by using different methods. It has been shown that the current state of research indicates that alignment of galaxies in structures is increasing with the mass of the structures. These results are discussed in light of their implications for the theory of galaxy formation.

RECONSTRUCTING THE HIDDEN LARGE-SCALE STRUCTURE OF THE UNIVERSE IN THE ZONE OF AVOIDANCE

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The Zone of Avoidance (ZoA), a region obscured by the Milky Way's foreground dust and high stellar density, represents a major challenge for mapping the extragalactic large-scale structure (LSS). This incompleteness prevents a full understanding of the local Universe's dynamics. This review summarizes direct observational mitigation strategies, such as blind 21-cm H I surveys (e.g., Parkes, ALFAZOA) and near-infrared mapping (2MASS, VVV), which penetrate the dust to reveal hidden galaxies and clusters. Because interstellar dust eventually blocks even our best multiwavelength efforts, indirect reconstruction is the only way forward near the Galactic equator. We evaluate classical statistical approaches like Wiener filtering and constrained realizations alongside advanced signal processing methods such as sparsity-based inpainting.

Furthermore, we explore recent deep learning methods, including Generative Adversarial Networks (GANs) for "darning" the ZoA and Convolutional Neural Networks (CNNs) for reconstructing 3D density and peculiar velocity fields. These integrated methodologies have successfully revealed key structures like the Great Attractor and the Vela Supercluster, moving us closer to a bias-free, whole-sky map of the cosmic web.

MULTIWAVELENGTH PROPERTIES AND ENVIRONMENT OF POLAR RING GALAXY CANDIDATES

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We present a consolidated catalogue of 179 visually inspected polar ring galaxy (PRG) candidates in the Sloan Digital Sky Survey (SDSS), compiled from existing catalogues and supplemented by seven objects discovered using our deep-learning approach and visual inspection of the SDSS ring-galaxy catalogue. For one of the newly identified PRGs, SDSS J140644.42+471602.0, we obtained aperture photometry from the ultraviolet (GALEX) to the infrared (WISE) and performed spectral energy distribution modelling with CIGALE. The inferred star formation history comprises two episodes: an old stellar population with an age of ~8.5 Gyr that dominates the stellar mass, and a younger population formed ~500 Myr ago. Its long e-folding timescale is more consistent with gas accretion from a satellite galaxy than with a major merger. We further used available SDSS spectra for 121 catalogue objects to classify their activity using the BPT diagram, finding that 64% show signs of nuclear activity — classified as composite, LINER, or Seyfert — while the remainder are purely star-forming. This may support a connection between gas inflow from polar structures and the fuelling of central black holes. We also examined the local environments of the seven newly discovered PRGs using neighbour counts within 3 Mpc and Voronoi tessellation. All reside in isolated or low-density surroundings, consistent with the expected destruction of polar rings in denser environments such as galaxy clusters. These results provide new observational constraints on PRG formation scenarios and highlight promising directions for future multiwavelength and environmental studies of this rare class of galaxies.

FROM OPTICAL VARIABILITY TO HOT-DUST REVERBERATION IN THE ISOLATED NLSY1 GALAXIES MRK 42 AND MRK 493

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We present an optical–infrared time-domain study of the isolated narrow-line Seyfert 1 galaxies Mrk 42 and Mrk 493, aimed at probing the connection between accretion-disc variability and the response of circumnuclear hot dust. The analysis combines ZTF optical and WISE/NEOWISE infrared monitoring, supplemented by ATLAS, SDSS, and Swift observations. Hot-dust reverberation delays were measured from FR/RSS realisations of the interpolated cross-correlation function after correcting the WISE light curves for the variable accretion-disc contribution. Both galaxies show significant long-term variability and positive optical-to-infrared delays. For Mrk 42, the observed-frame centroid lags are 54 days in W1 and 62 days in W2, corresponding to rest-frame dust-response radii of approximately 0.04 and 0.05 pc. For Mrk 493, the corresponding lags are 94 and 111 days, giving characteristic radii of approximately 0.08 and 0.09 pc. Independent pyZDCF calculations support the positive-lag solutions, while an extended ATLAS plus ZTF optical driver confirms the stability of the Mrk 493 measurements. For Mrk 42, paired FR/RSS realisations confirm that the inferred dust-reverberation lags are insensitive to subtraction of the approximately 47-day residual optical component.

Both nuclei exhibit optical bluer-when-brighter behaviour, while their infrared colour responses differ. Mrk 493 shows significant long-term W1–W2 colour evolution, whereas the corresponding trend in Mrk 42 is weak. For Mrk 493, the published Hβ reverberation lag confirms that the W1/W2-emitting dust lies outside the principal broad-line response region. The inferred dust-response radii are consistent with the low-luminosity extension and intrinsic

scatter of published dust size–luminosity relations. These results support a common disc–hot-dust reverberation framework for the two isolated NLSy1 nuclei, alongside source-dependent differences in optical activity and infrared colour behaviour.

DATA-DRIVEN CHARACTERIZATION OF GALACTIC SPIRAL STRUCTURE USING GAIA DR3 KINEMATIC TRACERS

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We present a method for determining Galactic spiral-arm parameters from Gaia DR3 kinematic tracers. These tracers are centroids of stellar spherical regions whose radial deformation velocities, estimated with the Ogorodnikov--Milne model, are statistically insignificant. Unlike baseline semi-automatic selection, the method estimates five Galactocentric arm distances by stacking transformed-coordinate distributions and derives a common pitch through variance minimization. Applied to ~10k centroids, it automatically recovers parameters for five spiral arms, with a common pitch of -10.3 degrees.

NGC 3521 AS THE MILKY WAY NEAR TWIN: SPECTRAL ENERGY DISTRIBUTION FROM UV TO RADIO DECAMETER RANGES

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Milky Way analogues (MWAs) are usually selected from structural and kinematic properties, but robust SED-based similarity criteria are limited by heterogeneous photometry and incomplete wavelength coverage. We present a homogeneous, aperture-photometry SED of the Milky Way near-twin NGC~3521 from the ultraviolet to the radio decameter range.

Fluxes are measured within a fixed elliptical isophotal aperture using GALEX, SDSS, WISE, Spitzer/MIPS, Herschel/PACS+SPIRE, and VLA data, and supplemented by meter/decameter constraints.

We report new observations obtained in Jan-Feb 2022 with the Ukrainian T-shape radio telescope and derive, for the first time, an upper limit in the 24--32~MHz band. The UV-to-decameter SED (27 points) is modelled with \textsc{CIGALE}, including a dedicated low-frequency radio prescription (\texttt{radio_extra}) that accounts for emission and absorption effects.

Using ZTF and NEOWISE data (2014--2025), we detect genuine nuclear variability; optical trends at $\sim 2''$ primarily trace the compact nucleus, while NEOWISE variability reflects a mix of nuclear changes and warm-dust emission within the larger aperture. The preferred fit yields $M_\star \simeq 6.0\times10^{10} M_\odot$, $SFR \simeq 1.65 M_\odot, yr^{-1}$, $M_{dust} \simeq 1.3\times10^{8} M_\odot$, and an effective dust temperature of ~23~K. The decameter constraint gives S28,MHz<11.22~Jy, consistent with expectations for a Milky Way-like system placed at 10.7~Mpc. We conclude that an integrated, homogeneous SED, especially below 100~MHz, provides a complementary diagnostic for identifying and validating MWAs and for interpreting how Milky Way properties would appear to an external observer.

ISOLATED GALAXIES AS THE MILKY WAY ANALOGS

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The search for galaxies analogous to the Milky Way (MWA) is a fundamental task in modern extragalactic astronomy. Such analogues serve as reference systems for studying the structural, dynamical, and evolutionary properties of our Galaxy in a broader cosmological context. Since we cannot observe the Milky Way externally, identifying similar systems elsewhere allows us to assess how typical or exceptional it may be in terms of morphology, environment, nuclear activity, and black hole properties. We investigate isolated galaxies with active nuclei as potential analogues of the Milky Way. A representative sample of isolated active galaxies was compiled using data from the 2MIG, SDSS DR8, and 2MRS catalogs. Morphological filtering and isolation verification were performed through cross-matching with multiple catalogs. The nuclear activity was classified using BPT and VO87 diagrams. Black hole masses in galactic centers were estimated using virial methods based on Hα line parameters. A final sample of 22 galaxies with active nuclei was proposed as the closest analogues to the Milky Way. The search for Milky Way analogues is one of the research topics of the LSST GSC collaboration

ALIGNMENT OF GALAXIES IN CROSS-LIKE SUBSTRUCTURES IN GALAXY CLUSTERS

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Galaxy orientations within the elements of the LSS of the Universe are not random. They depend both on the type of the structure element and on the morphological type of the galaxy, as well as on LSS evolution. Namely,

the contraction rate along a given axis is determined by the properties of the underlying dark-matter web, so the evolution of galaxy clusters can give rise to filamentary/cross-shaped substructures with non-random galaxy alignment.

For a sample of galaxy clusters with statistically significant cross-shaped substructures, we analysed the projected orientations of galaxies relative to these substructures on the celestial sphere. A substantial part of galaxies, especially the bright ones, show a persistent alignment along their local segment of the substructure. We suggest that such clusters form at the intersections of dark-matter filaments.

LUMINOSITY FUNCTION OF GALAXY CLUSTERS: A NEW VIEW BASED ON DATA FROM THE SLOAN DIGITAL SKY SURVEY

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The luminosity function is a primary diagnostic tool for mapping the large-scale structure and evolution of the Universe. Using photometric data from the Sloan Digital Sky Survey, we explore the properties of dense cosmic structures at two distinct scales. First, we derive the luminosity functions for member galaxies within individual cluster systems. Concurrently, we construct a comprehensive luminosity function for the entire population of galaxy clusters in our catalog based on their total luminosity. These complementary results are evaluated against prior studies by our team and interpreted in the context of theories of formation of galaxies and their structures.

BLAZAR S5 0716+714: INTERDAY VARIABILITY AND COLOUR PROPERTIES BASED ON BVRI PHOTOMETRY

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We present the results of a study of the multicolour optical variability of the blazar S5 0716+714 based on photometric monitoring in the B, V, R, and I bands conducted at the Alnitak Observatory, Spain. Analysis of the light curves revealed a critical trend breakpoint at MJD=61038, separating the photometric behaviour of the source into two qualitatively distinct phases. In particular, the slope of the linear fit to the B−I versus MJD relation changes from $\Gamma\approx-1.92$ to $\Gamma\approx-0.14$.

The first phase, before MJD≈61038, is characterised by pronounced brightness variations and chromatic behaviour: the R-band light curve follows the changes in the colour index. This behaviour indicates the dominance of injection and radiative-cooling processes affecting relativistic electrons accelerated by the passage of a shock wave. This phase also clearly exhibits a "bluer-when-brighter" (BWB) trend. During the second phase, after MJD≈61038, the blazar light curves reach a relatively stable and systematically brighter level, accompanied by an achromatic variability regime: the R-band light curve no longer follows the changes in the colour index. This variability pattern is interpreted as a consequence of a reorientation of the jet-emitting region relative to the line of sight, resulting in a change in the Doppler factor.

PRIMORDIAL BLACK HOLES: OBSERVATIONAL CONSTRAINTS AND GRAVITATIONAL-WAVE SIGNATURES

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For the 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.

SOME ASTEROID POSITIONS FROM THE TAUTENBURG AND BALDONE DIGITIZED ASTROPLATE ARCHIVES

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Our primary goal in processing the digitized negatives from the archives of the two Schmidt telescopes is to create an extended version of the stellar catalog of coordinates and photometric data of the Northern Sky Photographic Survey project. In addition, we also examine these data for recorded images of asteroids, comets, satellites of the major planets of the Solar system, and TNOs. Ultimately, using modern methods of digitizing negatives and processing the digitized images using the latest star catalogs, we obtain coordinates and photometric estimates of these objects with a sufficiently high accuracy, typical of photographic astrometry. Since past observations were conducted from 1963 to 2000, many of the identified and calculated positions of the asteroids are pre-discovery positions.

By processing 500 negatives from the Tautenburg 2-m Schmidt telescope, acquired between 1963 and 1989 and digitized with the Tautenburg Plate Scanner, we obtained 258 astrometric positions and V-magnitudes of asteroids. Of these, 97 are new positions of asteroids not in the MPC database. Among these, 40 positions correspond to the earliest observations of these objects in the world, known to the international community.

By processing negatives from the Baldone archive exposed with U and V filters, we obtained 1848 astrometric positions and magnitudes of asteroids, of which more than 400 are the earliest observations of these objects in the world. Work is currently ongoing to process the digitized negatives exposed with the R-filter and identify the positions of small Solar system bodies. An analysis of the obtained results was performed, which showed that the reduction processing of digitized data, together with the use of the modern Gaia DR2 star catalog as a reference, leads to better results in the positional accuracy of asteroids.

GLOBAL SLOW M = 1 MODE EMERGING IN A SELF-GRAVITATING TORUS

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This contribution is based on the results presented in our manuscript.

Large-scale non-axisymmetric structures are frequently observed in near-Keplerian systems dominated by a central mass, including eccentric nuclear stellar disks such as the double nucleus of M31 and molecular tori in active galactic nuclei. Despite numerous theoretical and numerical studies, the physical mechanism responsible for the spontaneous formation and long-term survival of global lopsided (m = 1) modes remains an open problem.

We investigate the secular evolution of an initially axisymmetric collisionless self-gravitating torus orbiting a dominant central object by means of direct three-dimensional N-body simulations performed with the high-order Hermite GPU code (ϕ-GPU). The calculations cover different torus-to-central-mass ratios and a range of initial orbital configurations in order to identify the conditions required for the development of global non-axisymmetric structures.

Our simulations demonstrate that a long-lived slow m = 1 mode naturally develops without externally imposed perturbations, producing a coherent overdensity that survives over secular timescales. The persistence of this structure is associated with apsidal alignment of eccentric particle orbits and nonlinear coupling between low-order azimuthal harmonics, including the m = 3 component. We further show that the instability operates only in sufficiently geometrically thick tori, highlighting its intrinsically three-dimensional nature. The resulting asymmetric mass distribution also induces a measurable displacement of the central mass from the system barycenter.

These results provide a self-consistent dynamical scenario for the formation of long-lived lopsided configurations in near-Keplerian systems and offer a possible explanation for asymmetric nuclear stellar disks and molecular tori observed in galactic centres.

SOLAR SYSTEM, EXOPLANETS AND NEAR-EARTH ASTRONOMY

INTERPLAY BETWEEN COLLISIONS AND YORP EFFECT IN ASTEROID EVOLUTION

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The rotational dynamics of asteroids are shaped by the continuous influence of two competing mechanisms: collisions and the non-gravitational YORP effect. In this paper, we investigate the limits of each mechanism's influence and propose a classification of evolutionary scenarios, dividing asteroids into three groups based on size.

For the largest objects, evolution is driven exclusively by collisions through direct momentum transfer. In contrast, for the smallest bodies, collisions become irrelevant, and the YORP effect acts as the sole driving force determining changes in rotational velocity.

The most complex case involves bodies of intermediate size. Non-destructive collisions here are not strong enough to directly alter angular momentum, but they are capable of changing the asteroid's macroscopic shape (for example, through cratering). This causes sudden changes in the YORP coefficient. As a result, a stochastic YORP effect arises: instead of continuous, directed evolution, the asteroid's rotational state demonstrates random fluctuations.

Since the intensity of solar radiation and the probability of collisions depend on the heliocentric distance, we compare the manifestation of these effects for near-Earth asteroids (NEAs) and main-belt asteroids (MBAs). In addition, we examine the specifics of binary systems and distinguish between the effects of classical YORP and the binary YORP (BYORP) effect.

By estimating the characteristic timescales of these processes, we determine which mechanisms (radiation or impact) are dominant for specific populations and size ranges, establishing the critical thresholds for their transition.

PHENOMENOLOGICAL MATHEMATICAL MODELLING OF EXOPLANET TRANSITS

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We have elaborated a complex of computer programs realizing improved algorithms of time series analysis of data with (generally, irregularly spaced) times (or other arguments). These programs have been used for analysis of photometry of 2500+ variable stars of different types – eclipsing, pulsating, eruptive.

The review chapter in the monograph was published in 2020kdbd.book..191A/abstract . The starting basic algorithms were reviewed in 1994OAP.....7...49A.

However, these improvements of methods of mathematical modelling may be used for a wider range of astronomical objects – active galactic nuclei, asteroids, every variable objects in radio, IR, optical, UV, X-Ray and gamma- ranges.

For the exoplanet transits (which are typically included in the "Variable Stars and Exoplanets" sections of conferences and national astronomical societies), there may be effectively used programs for phenomenological modeling prior to dezired physical modelling. The use of phenomenological modelling is justified by reducing dimension of parameters. E.g. x+y=z, thus y=z-x, but, knowing z, one may not simultaneously determine both x and y. Similarly, m=M-5+5lg(d). From pure photometrical observations, it is possible to get a (precise) phenomenological parameter "visible magnitude", but physical parameters "absolute magnitude" and "distance" are related. Similarly, the phases of the of the inner and outer contacts are 3 phenomenological parameters – the central phase, half-widths of the total interval of eclipse and an interval of total eclipse – depend on 3 physical parameters – radii of 2 stars, and an inclination angle (or, a related value of ratio of the minimal projection between the centers of the stars to the radius of the larger star). These samples are for a simple model. In reality, one has to take into account possible eccentricity of the orbit and of the shape of the (possibly rotating) star, possible spots, (asymmetric) limb darkening etc. The distribution of brightness is dependent on the wavelength (spectral energy distribution). So the "direct problem" – the computation of the light curve using fixed parameters is much simpler as compared to the "inverse problem" determination of the (too many) physical parameters.

The effective parameters of the light curve are time/phase of the following points: center of the eclipse/transits, outer and inner contacts, centers of the ascending and descending branches, which lead (for symmetrical minima) to a smaller number of important points for phenomenological modelling: center, inner and outer (mean) contact and mid ascending/descending branch – 4 points instead of a dozen physical parameters. Much larger number of parameters are needed for eclipsing binary systems, as there must be added nor only outer and inner contacts of the another eclipse, but also quadratures (phases 0.25 and 0.75).

For statistically optimal modeling of the complete curve, one may recommend the programs MCV (uavso.org.ua/mcv/MCV.zip) and NAV (2012Ap.....55..536A). Determination of the times of extrema with the best statistical accuracy may be done by the program MAVKA (uavso.org.ua/mavka), which includes 22 functions of 11 types with a possibility to fix the algorithm from these 11, or to choose automatically from all (or some selected) of these. Despite initially the program was developed for the

minima determination, it may be effectively used for transits, determining moments of both inner contacts, but also to determine outer contacts, splitting the data into 3 corresponding subintervals. The approximations have "jumps" between them, but often they are negligible as compared to the amplitude of the descending/ascending branches.

Examples of such approximations are shown.

COMPARISON OF TRANSITING EXOPLANETS RADII ESTIMATED BY USING TRANSIT DEPTH AND TIME INTERVALS METHODS USING DATA FROM THE KEPLER MISSION

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Estimating the radii of transiting exoplanets is a crucial task in modern astrophysics, as radius uncertainties lead to inaccuracies in subsequent exoplanet research, such as the analysis of their chemical composition or atmospheres. This work investigates the magnitude of the error in estimating transiting exoplanet radii caused by manifestations of stellar activity.

In the course of this study, we constructed light curves based on Kepler space telescope observations for 10 exoplanet systems. We established a theoretical model for estimating the planet-to-star radius ratio by calculating the time intervals between the first and second, and the first and fourth contacts of the disks of a planet and a star. A Python-based program was developed to construct and analyse the light curves and derive the necessary numerical results.

We compared the radii of the selected exoplanets calculated using the \"time interval\" method versus the transit depth method. The calculations demonstrated that the exoplanet radius tends to be overestimated when using the time interval method compared to the transit depth method. Furthermore, a trend was identified showing that the standard deviation of the planet-to-star radius ratio was, on average, higher for stars of lower spectral classes. This is consistent with the current understanding of higher stellar activity in cooler stars.

SPECTROPHOTOMETRIC STUDY OF THE GIANT PLANETS

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To answer numerous questions regarding the atmospheric dynamics of giant planets and to identify the patterns of atmospheric phenomena on their disks, it is essential to conduct long-term observations using ground-based and space telescopes equipped with high-precision optical instruments. Spectrophotometric study of planetary atmospheres with high spectral resolution, based on their constituent molecular gases, helps reveal various factors at play within the atmosphere. Studying these molecular gases makes it possible to investigate atmospheric and cloud structures, as well as the dynamics of physical processes occurring on the planetary disks. This study focused on molecular hydrogen, which constitutes the primary component of the giant planets' atmospheres.

Spectral analysis of molecular hydrogen is conducted based on the quadrupole lines of the absorption bands appearing in the visible and near-infrared regions of the planet's spectrum. These lines are sensitive to the high hydrogen abundance, the ortho-para hydrogen ratio, the vertical structure, cloud distribution, and the pressure-temperature profile of the observed atmosphere.

In this study, the H2(4-0) molecular hydrogen band in the visible region was investigated using spectra of giant planets obtained between 2014 and 2021. These spectra were acquired at the Cassegrain focus of the 2-meter telescope at the Shamakhy Astrophysical Observatory, utilizing an echelle spectrograph equipped with a CCD detector and offering spectral resolutions of R=14.000, 28.000 and 56.000. Based on the physical parameters of the S(0) (6435.03 Å) and S(1) (6367.76 Å) quadrupole lines of this band, the pressure P (atm) at the depth of line formation, the rotational temperature Trot (K), and the molecular hydrogen abundance U(H2) (km•amagat) in the atmosphere above the cloud layer were determined. These values were calculated for various regions of the Jupiter and Saturn disks, as well as for the full disks of Uranus and Neptune.

Conducting spectrophotometric studies of giant planet atmospheres in the molecular hydrogen absorption line regions, as well as calculating specific atmospheric parameters, is a crucial task for shedding light on the evolution of these atmospheres and gaining a proper understanding of the physical processes occurring within them.

METHANE (CH4) ABSORPTION AROUND Λ6800 Å IN THE SPEKTRA OF THE PLANETS URANUS AND NEPTUNE

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Studying the structure of molecular gas absorption bands in the spectra of giant planets can provide important information about the physical properties of their atmospheres. Based on the relative intensities and half-widths of the absorption lines within these molecular bands, it is possible to determine the rotational temperature and pressure in the atmospheres of these planets.

Methane gas accounts for approximately 2–4% of the atmospheres of the planets Uranus and Neptune. Strong and weak methane (CH_4) absorption bands are observed in the visible and infrared regions of these planets spectra. The methane absorption band at λ 6800 Å ($5\nu_3$) first detected by T. Owen in the visible spectrum of Uranus,provides reliable information not only about the methane itself but also about the upper troposphere of these planets atmospheres. Many researchers have conducted studies of this band and, based on it, of the atmospheres of these planets.

In this study, absorption lines of the R-branch—arising from rotational transitions within the methane (CH4) λ6800 Å 5ν3 absorption band in the spectra of the planets Uranus and Neptune were identified, and their relative intensities and half-widths were determined. Based on the relative intensities of these lines, the rotational temperature at the atmospheric depth where the lines are formed was established. Spectra of Uranus (obtained on August 30, 2017) and Neptune (obtained on September 17, 2017) from the 2-meter telescope at the Shamakhy Astrophysical Observatory (ShAO) were used here. The spectra were acquired with a spectral resolution of R=28,000 using a fiber-fed echelle spectrometer equipped with a CCD detector at the Cassegrain focus. The processing of the obtained echelle spectra was carried out using the DECH software package.

Consequently, it has been determined that the rotational temperature at the depth where absorption lines form ranges from 78 to 102 K for Uranus and from 74 to 112 K for Neptune. These temperature values further demonstrate that the temperature at the depth where methane bands form exceeds the freezing point of methane, a phenomenon likely attributable to the planet's internal energy. The specific mechanisms generating this internal energy have not yet been fully explained scientifically. The higher temperature observed on Neptune compared to Uranus may be linked to Neptune's stronger thermal radiation.

SPACE DEBRIS MITIGATION IN THE NEAR-EARTH ENVIRONMENT: ASSESSING THE EFFECTIVENESS OF INTERNATIONAL GUIDELINES AGAINST OBSERVED ORBITAL TRENDS

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The rapid expansion of space activities has significantly increased the population of man-made objects in the near-Earth environment and has raised concerns about the long-term sustainability of orbital operations. International organizations have developed a series of space debris mitigation measures, including the Inter-Agency Space Debris Coordination Committee Space Debris Mitigation Guidelines, the United Nations Committee on the Peaceful Uses of Outer Space Space Debris Mitigation Guidelines, the Guidelines for the Long-Term Sustainability of Space Activities, and related technical standards. However, the space debris population continues to grow.

This study examines the effectiveness of international space debris mitigation measures by comparing their main objectives with observed trends in the near-Earth orbital environment. Data from the European Space Agency's Space Environment Reports and the Space Debris User Portal are used to analyze changes in the population of tracked orbital objects, post-mission disposal practices, atmospheric re-entry, fragmentation events, and the evolution of the debris environment in near-Earth orbit.

The analysis highlights a clear discrepancy between improving compliance with specific mitigation practices and the continued growth of the overall debris population. In particular, improvements in mission disposal and reentry practices suggest that mitigation standards can influence operational behavior. However, fragmentation events, legacy objects, increasing space activity, and incomplete implementation continue to contribute to the net increase in debris.

The study concludes that preventive mitigation remains essential, but may not be sufficient on its own to ensure the long-term sustainability of the increasingly congested Earth orbital regions.

LUNAR PHOTOMETRIC FUNCTION IN THE NEAR INFRARED TO ACCOUNT FOR THERMAL COMPONENT IN THE SPECTRA

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Global mineralogical mapping of the Moon in the spectral range of ~0.8-5.0 μm and complete characterization of water/hydroxyl feature near 3.0 μm at high spatial and spectral resolutions remain actual tasks of remote sensing from the orbit (JAXA Kaguya, ISRO Chandrayaan-1,2 missions). Mineralogical studies using near-IR remote spectra inevitably includes differentiation between energy reflected by the surface due to solar irradiance and thermal emission which is become significant for wavelength more than 2.5 μm. Therefore, one need to solve the thermal-conductivity equation for regolith-like media with the necessary initial and boundary conditions.

We use a simplified model of thermal conductivity, suggesting that the lunar surface is a semi-infinite plane and its properties (density, the heat capacity, the thermal conductivity) do not vary horizontally. Crucial parameter of the model is emissivity as a function of surface temperature which is, in turn, a function of albedo, surface properties and local photometric conditions. Spectral directional emissivity added to the directional-to-hemispherical reflectance comprises the unity. Estimation of the reflectance requires the calculation of phase integral, i.e. integration of phase function over the whole domain of emission angles and IR wavelengths.

Using the IR data for several lunar mare and highland sites from Chandrayaan-1 M3 spectrometer we approximated phase function for phase angles from 0 to 180 degrees and 0.5-3.0 μm wavelength range. We use Akimov' parameter-free disk function. Then obtained values of phase function parameters have been approximated to the Chandrayaan-2 IIRS range up to 5 μm. Corresponding phase integrals have been calculated; we note the increasing of amplitude of phase integral with wavelength. We confirm narrow small opposition spikes in phase curves in IR which are more pronounced for bright fresh crater features. New IR lunar photometric function is implemented in reducing of IIRS lunar spectra for search of lunar volatiles.

SEARCH FOR EVIDENCE OF SPACE WEATHERING AMONG ASTEROID FAMILIES OF VARIOUS AGES

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Asteroid families provide a unique natural laboratory for studying space weathering because their members are thought to originate from the same parent body and therefore share similar initial compositions. Since asteroid families span a wide range of ages, they allow the evolution of surface spectral properties to be investigated as a function of exposure time to the space environment.

In this study, we performed a comprehensive investigation of the effects of space weathering on the surfaces of asteroids belonging to 24 asteroid families spanning a broad range of ages and two main taxonomic classes, including 11 S-type and 13 C-type families. The degree of space weathering was quantified using the $a*$ parameter, which serves as a proxy for the spectral slope. Family ages were estimated by constructing V-shaped distributions in the proper semi-major axis – absolute magnitude parameter space. The analysis was based on photometric data from the SDSS MOC4, Gaia, and SkyMapper surveys. Statistically significant correlations were found between the spectral slope proxy $a*$ and the logarithm of family age. The results reveal distinct evolutionary trends for S- and C-type families, indicating that the spectral effects of space weathering depend on the mineralogical composition of asteroid surfaces. In addition to investigating its temporal evolution, we examined the dependence of the color indices ($g-i$, $g-r$, $i-z$, $u-g$) on absolute magnitude for 16 S-type asteroid families. Because absolute magnitude is correlated with asteroid size, this analysis provides an indirect test of the relationship between spectral properties and surface age, under the assumption that smaller family members have, on average, younger and less weathered surfaces than larger asteroids.

ON THE POSSIBILITY OF USING CIVIL TWILIGHT TO CALIBRATE POLARIMETRIC MEASUREMENTS

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This paper demonstrates how the long-known fact of the occurrence of linear polarization as a result of single scattering in the Earth's atmosphere can be used to calibrate astronomical polarimetric measurements. Atmospheric linear polarization has a constant plane, the position of which is related to the position of the Sun and can therefore be calculated with any accuracy. In polarization measurements, considerable time is spent determining the zero point of the instrument's position angle based on measurements of stars with high polarization. Using, for example, twilight measurements followed by calculations using the presented method significantly simplifies this task and reduces the amount of observing time at night. Methods for increasing the accuracy of the obtained results are also presented.

IMAGING POLARIMETER FOR OMT-800

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A solution to the problem of determining the full Stokes parameters (Q, U, V, I) with minimal light loss is proposed, using only standard optical components commercially available from leading optical companies. To solve this problem, it is proposed to combine two classical approaches to splitting the light beam at the device input. Specifically, in the following sequence: a rotating analyzer, a collimation scheme, and splitting the incident radiation using static polarizing components. Splitting of the incident radiation is achieved using commercially available thin nanostructured polarizing beamsplitters (Wire-Grid Beamsplitters). A 7-component achromatic phase-shifting quarter-wave plate, installed upstream of the aforementioned beamsplitters, is used as the analyzer. After splitting the beam into four polarization states, images of the source are recorded by two radiation receivers: four images on each receiver. The need to use two receivers is a direct consequence of the fact that nanostructured polarizing beam splitters are currently produced only for two wavelength ranges: 400-700 and 700-1100 nm.

MONITORING OF OPERATIONAL AND RETIRED SATELLITES OF THE STARLINK CONSTELLATION

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The rapid expansion of low-orbit satellite constellations, particularly the Starlink system, is having an increasingly significant impact on astronomical observations. While most attention is typically focused on operational spacecraft, failed satellites, which have lost their orientation and entered uncontrolled rotation, can pose an additional challenge. Their photometric behavior is characterized by both periodic brightness variations due to rotation and intense, short-lived specular flares that occur under favorable illumination geometry.

This paper presents the results of joint photometric observations of Starlink v2 satellites conducted by a network of observatories. The photometric characteristics of several operational spacecraft, as well as one inactive satellite, Starlink-34343 (NORAD ID 64157), exhibiting rapid rotation, are analyzed. Brightness time series are

obtained, containing regular brightness variations and numerous bright specular flares. The possibility of determining and predicting the orientation of such satellites is discussed. An unusual change in the angular velocity of the 64157 satellite's rotation is noted. The impact of the observed photometric features on wide-field and deep astronomical surveys is also discussed. It is shown that while the average brightness of operational satellites determines their systematic contribution to image contamination, uncontrolled rotating satellites can create significantly stronger short-term light pollution due to specular reflections of sunlight. Such events can lead to bright artifacts in astronomical images that must be taken into account. The obtained results emphasize the need for systematic monitoring of the photometric properties of both operational and failed satellites.

RESIDENT SPACE OBJECTS LOTOS SERIES LIGHT CURVE SIMULATIONS

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Simulation of real light curves of low-orbit RSO objects of the LOTOS series (NORAD: 36095, 43032, 43657, 40358, 47546, 52202, 54381, 58148) was carried out using the Blender environment with GPU. Selected light curves of both inactive and active spacecraft of this series were simulated, their orientation was determined and rotation periods were confirmed. The simulated light curves differ from the experimental curves within 2-3 RMS. A 3D model of the satellite of this series was developed according to open sources and photographs.

This modeling technique was developed by us for objects of known shape, tested on the TOPEX/Poseidon satellite. The selection of initial modeling parameters was improved using the open-source framework Optuna for hyperparameter optimization to automate hyperparameter search.

The photometric light curves used for the simulation were obtained on a special TwinPhot photometric telescope, which consists of two separate Newtonian optical tubes (F/5) with different photometric filters (B and V), and separate CCD cameras (QHY174M-GPS) mounted on a SkyWatcher AZ-EQ6 Pro mount.

INTEGRATION OF RMS STATIONS INTO THE UKRAINIAN METEOR OBSERVATION NETWORK (UMON) AND THE GLOBAL METEOR NETWORK (GMN): INFRASTRUCTURE, METHODS AND THE FIRST SCIENTIFIC RESULTS

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The report presents the results of modernizing the meteor patrol of the Astronomical Observatory of Taras Shevchenko National University of Kyiv by integrating three automated RMS (Raspberry Meteor Station) stations into the Ukrainian Meteor Observation Network (UMON) and the Global Meteor Network (GMN).

The technical foundation of the system is based on Raspberry Pi 4 microcomputers equipped with highly sensitive Sony STARVIS IMX462 sensors. To ensure fault tolerance, a hybrid network architecture with channel redundancy (wired Internet + 4G/LTE 900/1800 MHz) and PoE (Power over Ethernet) technology was implemented. The three stations (UA0008, UA0009, UA000A) are strategically located in the Kyiv region and oriented to monitor the northeastern sector of the sky.

Astrometric calibration, trajectory triangulation, orbit calculation, and dark-flight modeling are performed by the automated RMS pipeline using the WMPL (Western Meteor Physics Library) library. The Monte Carlo method is applied for error estimation.

During the operational period, the network detected numerous sporadic and shower meteors. Among a series of multi-station (double-station and multi-station) events, a bright fireball on June 21, 2026 (20:48:20 UT) was analyzed in detail. The event was recorded simultaneously by four stations (including UA000A in cooperation with amateur stations) with an optimal convergence angle of 81.79°. The determined heliocentric orbit of the body (a = 2.63 AU, e = 0.61, i = 12.15°, T_J = 3.075) indicates a sporadic asteroidal origin. The high precision of the measurements (terminal height error of ±9 m) and the low ablation terminal height (~29.5 km) allowed for the prediction of the strewn field ellipse for the potential meteorite fall zone near the village of Makarivka, Kyiv region. The meteoroid's terminal mass (the mass with which the body enters the dark-flight phase), estimated at ~15 g, was obtained using the dynamic method based on the deceleration analysis of the body in the atmosphere. However, due to intense fragmentation and the small initial mass of the body, the probability of a macroscopic meteorite (with a mass of ~15 g) landing within this ellipse is extremely low.

The presented analysis is considered primarily as a successful validation of the complete computational cycle – from automatic detection of the phenomenon to predicting the meteorite fall zone. The obtained results confirm the high efficiency of the implemented infrastructure and its readiness for rapid response to fireball events with high meteorite-producing potential.

STATISTICAL ANALYSIS OF PHYSICAL PROPERTIES OF THE HOT POPULATION

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The Kuiper Belt is a vast reservoir of icy bodies located beyond the orbit of Neptune, extending from approximately 30 au to more than 50 au from the Sun. Thousands of trans-Neptunian objects (TNOs) have been discovered to date, revealing a remarkable diversity of dynamical classes and physical properties. As one of the best-preserved remnants of the primordial planetesimal disk, the Kuiper Belt provides unique insights into the formation and early evolution of the Solar System.

Among the different dynamical populations, the Hot Population in the Kuiper Belt is of particular interest. These objects are characterized by relatively high orbital inclinations and eccentricities and are thought to have been implanted into their current orbits during the migration of the giant planets. Consequently, their physical properties preserve important information about the conditions in the primordial Solar System and provide valuable observational constraints on models of planetary migration and the origin of trans-Neptunian populations.

In this work, we present a comprehensive statistical analysis of the physical properties of the Hot Population in the Kuiper Belt based on a sample of more than 2,000 objects. The study examines the distributions and correlations of orbital inclination, absolute magnitude, geometric albedo, color indices, and other available physical parameters. The resulting statistical relationships provide a robust observational framework for future numerical simulations aimed at investigating the origin and dynamical evolution of the Hot Population in the Kuiper Belt.

DETERMINATION OF TESS EXOPLANET PARAMETERS FROM UNISTELLAR EVSCOPE 2 OBSERVATIONS

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We discuss exoplanet parameters derived from light curves obtained with the Unistellar eVscope 2 telescope. Our objects were selected based on two criteria: a sufficiently bright host star and a predicted TESS transit that falls entirely within the accessible sky region. All our observational datasets underwent standard digital processing. Test-frame evaluations show that the stacking technique employed in Unistellar digital photometry yields errors low enough to work reliably down to magnitude 15^m. Typical error values are on the order of a few minutes for the timing and a few thousandths for the stellar flux.

Exoplanet parameters were calculated using a physical model of the stellar surface brightness distribution. The computations were performed with an original Colab code built on the BATMAN (BAsic Transit Model cAlculatioN) package. Limb-darkening coefficients for the host star were obtained with the SCO-LDC calculator.

The resulting exoplanet parameters agree, within the uncertainties, with the values listed in the NASA Exoplanet Archive, confirming the capabilities of the Unistellar eVscope 2 telescope.

DEVELOPMENT OF A SPECIALIZED CATALOGUE OF COMETARY ACTIVITY: OUTBURSTS, FRAGMENTATION PROCESSES, AND SOLAR ACTIVITY RELATIONSHIPS

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This study focuses on the investigation of cometary brightness outbursts and fragmentation processes, with particular emphasis on the development of a specialized catalogue of comet activity. Cometary outbursts and fragmentation events represent important phenomena for understanding the physical evolution of cometary nuclei, the mechanisms of their activity, and the influence of internal and external factors on small bodies of the Solar System. Despite the availability of numerous observational records, information on cometary activity events remains dispersed among different sources, making systematic statistical analysis difficult.

The catalogue is being compiled by integrating observational data on comets exhibiting brightness outbursts and fragmentation events, including the dates and characteristics of activity events, orbital parameters, possible encounters with meteor streams, and corresponding solar activity indices, particularly sunspot numbers.

Based on the analysis of 188 cometary outburst events, 116 active comets, and 102 meteor streams with reliable orbital elements, a structured database is being developed to identify possible relationships between cometary activity, solar variability, and orbital environment. The collected dataset enables the investigation of statistical distributions of outbursts and fragmentation events, as well as the assessment of possible factors influencing changes in cometary activity.

The catalogue will provide a comprehensive data source for statistical studies of comet evolution and future applications of machine learning methods aimed at revealing hidden patterns, identifying significant parameters, and developing approaches for predicting cometary activity and fragmentation events. The developed database will serve as a foundation for further studies of the physical and dynamical evolution of comets and other small bodies of the Solar System.

ANALYSIS OF THE CANON EOS CAMERAS CMOS SENSORS SENSITIVITY

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This paper presents an alternative methodology of studing the response of Canon EOS camera CMOS sensors to variations in output signal predictors: exposure duration T, ISO setting, and sensor illuminance E. Simple regression equations are obtained based on the linear approximation of relationships S(T), S(ISO), and S(E): $S(x)=K*x+A$ for linearly, or $\lg S(x)=(1+a)\lg x+b$ for logarithmically scaled operands of functions S(x). Here K, A, a, b are the constants of the equations. In the second case the sensor's output signal depends on its predictor x as follows:$S(x)=C(x)x^{*}xa$. Here $\lg C(x)=b$, C(x)x is the output signal component proportional to the predictor, and x to the a-th power is the nonlinearity factor of the function S(x). The factor is close to 1 in the region of S(x) linearity.

The sensor's response to changes in level of output signal predictor (sensitivity) is the first derivative with respect to the argument ($S'(x)=dS/dx$) of S(x) function. In

that case S'(T)=C(T), S'(ISO)=C(ISO). At the same time S'(E)=K, since the dependence S(E) is linear one but not proportional, as evidenced by the results of linear approximation of its experimental data. It is desirable to determine the sensitivity values C(T) and C(ISO) at identical E levels, and it makes sense to normalize them to the fixed predictor levels used to obtain the baseline photometric data, – eithe ISO or T. In accordance, Cn(T)=C(T)/ISO, Cn(ISO)=C(ISO)/T. The value K = S'(Em) should be normalized to the corresponding fixed values of both predictors, ISO and T: Kn=K/(T*ISO).

The analysis results indicate that parameter Kn should be considered more informative and convenient for the comparative analysis of sensitivity in R, G, and B sensor channels. The Kn sensor values for two full-frame cameras Canon EOS 5D MIII, MIV, Canon Eos 6D MII and one small-format camera Canon EOS 400D, calibrated at arbitrary levels of the T and ISO predictors, are presented in the 4 rows below for R, G, B channels corresponding. Here, [Kn]=DN/(Lx*S) is the dimension of this parameter.

Canon EOS 5D MIV:ISO=100 T=1.0s Kn=76.5 133.4 79.5
Canon EOS 5D MIV:ISO=100 T=10.4s Kn=74.9 130.3 78.5
Canon EOS 6D MII: ISO=1008 T=2.0s Kn=74.8 136.1 67.7
Canon EOS 400D: ISO=800 T=3.2s Kn=19.0 36.9 21.2.

ENIGMATIC ORANGE MATERIAL PATCHES ON ASTEROID (4) VESTA

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With a mean diameter of 525 km, Vesta is the second most massive body in the main asteroid belt and one of the few largely intact differentiated planetesimals, preserving evidence of early Solar System evolution. Its differentiated structure is supported by the close spectral similarity to howardite–eucrite–diogenite (HED) meteorites, and it is recognized as the parent body of the largest asteroid family in the main belt.

Observations by NASA's Dawn mission revealed pronounced compositional heterogeneity across Vesta's surface, including localized deposits referred to as orange material or light mantle material. These deposits occur as patchy, irregular units, commonly associated with crater rims and ejecta blankets, indicating an impact-related origin. Their distinctive spectral properties have led to several proposed formation mechanisms, including impact melt, distal ejecta, and mixtures of indigenous crustal and exogenic material.

In this study, we present a comprehensive analysis of all identified orange material patches on Vesta. Multispectral images acquired by the Dawn Framing Camera were analyzed using the color-ratio technique to identify and characterize these deposits. Visible spectra of representative patches were compared with those of adjacent terrains, while their morphology, spatial distribution, and relationships to topographic features were investigated. We also examined correlations between patch properties, including color ratios, edge sharpness, characteristic size, and areal extent, and compared their global distribution with crustal thickness and density models.

Assuming an impact-melt origin, we estimated the thickness of the orange material layer from the dimensions of the largest fresh craters superposed on the deposits. Independent estimates based on crater morphology indicate a minimum layer thickness of approximately 30–50 m for the largest patches. The compiled geological, spectral, and morphometric evidence was further used to test the hypothesis that the orange material originated from intrusive dike-related processes.

Our results provide new constraints on the origin, emplacement mechanisms, and geological evolution of orange material on Vesta, improving our understanding of impact-generated surface processes on differentiated asteroids.

COMIMPOL SOFTWARE FOR ASSEMBLING A USER PIPELINE TO PROCESS IMAGE POLARIZATION OBSERVATIONS

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Polarimetry is one of the most informative methods for studying the physical properties of cometary dust. The degree of linear polarization of scattered solar radiation is determined by the size, shape, porosity, and chemical and mineralogical composition of dust particles. Unlike photometry, polarimetric observations require significantly higher demands on data quality and processing. Typical values of the degree of linear polarization of a cometary coma are only a few percent, so obtaining reliable results requires a high signal-to-noise ratio, careful calibration, and consideration of instrumental polarization and atmospheric effects. Furthermore, processing includes calculating the Stokes parameters, combining images obtained at different positions of the polarization analyzer, and constructing maps of the distribution of the degree and angle of polarization. The diversity of polarimeter designs significantly complicates the development of universal software for processing such data. This work presents the ComImPol software package, developed by us, for processing polarimetric images of extended objects, with an emphasis on the study of comets and their dust components. The package is implemented in Python and has a flexible architecture, allowing it to be adapted to various instruments and observing programs. ComImPol allows adopting image processing to user tasks. For example, it helps to automate image calibration, constructing maps of the Stokes parameters, the degree and angle of linear polarization, and radial coma polarization profiles. The program has already been successfully tested in processing observations of comets C/2012 S1 (ISON) and 3I/ATLAS, demonstrating the high stability of its algorithms and the reproducibility of the resulting polarimetric characteristics.

DETERMINING TELESCOPE COORDINATES FROM ASTROMETRIC OBSERVATIONS OF LOW-EARTH-ORBIT ARTIFICIAL SATELLITES

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In the context of growing geopolitical tensions, the integrity and availability of navigation information provided by Global Navigation Satellite Systems (GNSS) are increasingly affected by interference, spoofing, or even complete signal denial. This creates a need for alternative methods of determining the coordinates of an observing site and synchronizing time when real-time access to GNSS is unavailable.

One possible approach is to estimate the coordinates of an observing site from astrometric observations of low-Earth-orbit (LEO) objects whose orbits are either well known or can be predicted with high accuracy.

We present the observational methodology, discuss the comparison of astrometric measurements with the orbital ephemerides of reference objects, and describe an algorithm for estimating the coordinates of the observing telescope. Since the achievable accuracy depends not only on the precision of the astrometric measurements but also on the accuracy of the reference orbital ephemerides, particular attention is also given to assessing and monitoring the quality of those ephemerides.

We demonstrate that the proposed method enables the independent determination of both the time offset and the geocentric coordinates of the observing site. When the orbital ephemerides of the reference objects are accurate to better than 1 m, the method can determine the site coordinates with an accuracy up 1 m and the time offset with an accuracy on the order of 0.1 ms.

NETWORK OF REMOTE OBSERVATION STATIONS

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Ground-based optical observations of resident space objects (RSOs) provide essential astrometric and photometric data for space situational awareness (SSA). These data are used for orbit refinement, conjunction assessment, detection of anomalous orbital behaviour, and other tasks related to monitoring the near-Earth space environment.

Observations of low-Earth-orbit (LEO) RSOs are highly sensitive to weather conditions and require frequent updates. Gaps in observational data reduce the accuracy of the derived orbital elements and may make continued independent tracking difficult without external data sources. To address this limitation, a network of small, geographically distributed autonomous observation stations is currently under development. The placement of these stations at low-light-pollution sites is expected to improve data quality, increase observation frequency, and provide more continuous coverage of selected RSOs.

Manual operation of a geographically distributed network of this scale would be impractical given the available human resources. Automation is therefore essential for coordinating observations and ensuring consistent operation of individual network nodes. We present the concept of a distributed network of autonomous optical stations designed to operate with minimal human intervention.

To meet the operational requirements of such a network, we evaluate the Automated Observation System (AOS), software developed to manage positional RSO-tracking workflows. Based on a modular architecture, AOS includes an automated scheduler that retrieves Two-Line Element (TLE) data, computes ephemerides via SGP4, and filters potential observations by solar elevation, RSO visibility, and lunar phase. It also implements priority-weighted scheduling algorithms to maximise observational yield.

An observing module controls the mount and camera and employs an Image Fusion Technique (IFT) to improve the signal-to-noise ratio for faint RSOs. Software solutions with these capabilities can provide a framework for autonomous scheduling, hardware control, image acquisition, and coordinated data collection across geographically distributed observation nodes, thereby supporting the development of independent and continuously operating SSA capabilities.

ROTATIONAL CHARACTERISTICS OF LARGE ASTEROID FAMILIES

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We analyze the rotational and optical properties of the 29 largest main-belt asteroid families. For each family, we constructed distributions of the a* parameter, albedo, lightcurve amplitudes, rotation periods, and age estimates inferred from V-shapes. The largest differences between families are found in the lightcurve amplitude distributions. Thirteen families contain objects of multiple taxonomic classes, and two families show comparable populations of taxonomically distinct groups. Eight families with expected V-shapes do not display a clear structure. We find a weak correlation between the mean lightcurve amplitude and family age. We also assessed the feasibility of estimating asteroid lightcurve amplitudes from the scatter of ZTF photometric measurements. The method was validated using members of the Maria family with reference amplitudes available in the ALCDEF database. The amplitudes inferred from the ZTF scatter differed from the ALCDEF values by up to a factor of two in either direction; however, the deviations showed no systematic bias. This suggests that, although the method is unsuitable for precise amplitude determinations of individual objects, it can provide statistically meaningful amplitude estimates for large asteroid populations. The DAMIT database was used to investigate the distribution of spin directions within asteroid families.

ANALYTICAL MODEL OF SOLAR ILLUMINATION DURATION FOR NEAR-EARTH SATELLITES

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The objective of this work is to examine the duration that near-Earth satellites spend in penumbra within the framework of a refined model of illumination for artificial satellites and to develop an analytical model of solar illumination for near-Earth satellites that accurately accounts for the second and third zonal harmonics in the geopotential expansion.

In near-Earth space, satellites can enter the Earth's shadow and penumbra for extended periods. To model them, we used a circular cone approximation based on a circle with the Earth's mean radius. The satellite's motion is modeled using a variable Keplerian orbit. The computer model allows us to determine, with a specified degree of accuracy, the duration of a satellite's stay in the Earth's shadow and penumbra.

We have modeled the duration of solar illumination of low-orbit satellites throughout the year in the Earth's shadow and penumbra within the framework of an analytical model of two fixed centers. The simulation results will allow for a more accurate determination of the influence of solar radiation and the solar wind on satellite motion over a long period of time.

Shadow phenomena occur as a result of the Sun casting enormous cones of shadow and penumbra in near-Earth space. The model employs analytical cone equations that account for changes in the Sun's coordinates over time.

The duration of a satellite's stay in a specific zone depends on the altitude of its orbit above the Earth's surface, the time of day at any season, the Sun's position relative to the Earth, other elements of the satellite's orbit, and the shape of the Earth, which we have taken into account to a significant extent.

The results obtained will make it possible to use the additional acceleration of satellites caused by radiation effects to alter the orbits of space debris and clean up near-Earth space.

MONITORING OF NEAR-EARTH SPACE AT THE OBSERVATORY ON PIP IVAN MOUNTAIN

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Observing the night sky to detect temporary and moving astronomical objects has become an important part of modern observational astronomy. In addition to traditional telescopic studies, wide-angle optical systems, in particular cameras for observing the entire sky, are actively used. With the growing interest in detecting near-Earth objects (NEOs), artificial satellites and space debris, there is a need for methods that can automatically and reliably identify such objects among large amounts of data. Continuous observations of the entire sky make it possible to record bright meteors, the trajectories of artificial satellites, and other fast-moving objects that usually go unnoticed during targeted telescopic observations.

This work presents the detection of moving objects using instruments installed at an Observatory located in the Ukrainian Carpathians on Pip Ivan Mountain (2022 m above sea level).

GROUND-BASED VERIFICATION OF TESS TRANSIT EXOPLANET CANDIDATES WITH UNISTELLAR TELESCOPE DIGITAL PHOTOMETRY

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We present the results of our observations of exoplanet candidates obtained with the Unistellar eVscope 2 telescope at the Physics and Astronomy Department of the I.I. Mechnikov Odesa I.I. Mechnikov National University in the 2025 observing season. This work aimed to determine the transit curve parameters and derive the properties of candidate exoplanets. The model calculations were carried out taking into account the stellar limb darkening.

Our light curves of TOI-7425.01 and TOI-7343.01, both discovered in 2025, confirm the predicted mid-transit time, transit duration, and depth. The exoplanet parameters derived from our observations are in good agreement with the values listed in the NASA Exoplanet Archive. For TOI-3567.01, discovered in 2021 and still having candidate status, the discrepancy with the predicted ephemeris is significant.

We confirm the presence of planets around TOI-7425 and TOI-7343, while TOI-3567.01 requires additional observations.

PHOTOMETRIC ANALYSIS OF LUNAR REGOLITH IN IMP MACLEAR-1

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There are several theories regarding the origin of photometric anomalies, such as Irregular Mare Patches (IMPs). Largest examples of IMP — such as Ina and Maskelyne — have been extensively studied to access mechanisms of their formation and evolution. However, numerous inconsistencies remain for smaller IMPs, such as Maclear-1, whose volcanic origin and timing are still under debate.

Maclear-1 IMP is located in Mare Tranquillitatis (latitude 8.89°, longitude 21.48°), measures approximately 430 m across. The host mare in the surrounding area has an estimated age of 3.68 Ga. The anomaly has an asymmetrical, irregular shape with varying depths (averaging ~10 m) compared to the surrounding flat areas of undisturbed regolith.

We carried out photometric study of the region with LROC NAC data of 0.5–1 m per pixel resolution. We applied photometric correction methods to obtain the albedo phase dependence in a wide range of phase angles from 10° to 92°, incorporating local topography derived from the same images. This ensured high accuracy of a digital elevation model we created and co-registration of all images within a consistent coordinate system.

We produced the equigonal albedo phase ratio EA(62°)/EA(24°) which clearly reveals pronounced photometric anomalies: light spots correspond to the Maclear-1 IMP formation itself, dark features represent cliffs and landslide structures, and gray areas indicate normal, undisturbed lunar regolith. We note striking differences in the optical properties of various selected areas, inverted behavior in "bumpy" regions compared to the surrounding regolith, and significant variations in surface roughness between "blocky" and rocky zones compared to other surface groups.

A zoning map of the photometric anomaly region was produced using the correlation diagram "Albedo – Phase ratio". Maps of the two-parameter photometric phase χ-function were also built, clearly revealing the photometric features of the anomaly against the background of the surrounding regular regions.

CRYOVOLCANISM ON PLUTO

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Cryovolcanism is one of the key endogenic processes on icy bodies of the Solar System, involving the eruption of volatile materials such as water, ammonia, and methane in liquid or ductile form instead of molten silicate rock. Data returned by the New Horizons mission have provided compelling evidence for cryovolcanic activity on Pluto. The most prominent candidate cryovolcanic features include the large dome-shaped edifices Wright Mons and Piccard Mons, as well as the Virgil Fossae and Viking Terra regions, where deposits interpreted as cryolava flows are associated with extensive tectonic fault systems. The low density of impact craters on these terrains indicates their relatively young geological age.

This study reviews current interpretations of the mechanisms driving cryovolcanism on Pluto, where the primary heat source is believed to be the decay of radioactive elements within the dwarf planet's interior. Spectral observations suggest that the erupted material consists predominantly of water ice mixed with ammonia, methane, nitrogen, and carbon monoxide, which lower the melting temperature and viscosity of the cryomagma. Particular attention is given to the detection of tholins—complex organic compounds whose presence may indicate that material from Pluto's interior has been transported to the surface.

The occurrence of ammonia on the surface provides strong evidence for relatively recent cryovolcanic activity, as this compound is gradually destroyed by solar ultraviolet radiation and cosmic rays on geological timescales. These findings indicate that cryovolcanism has played a significant role in the geological evolution of Pluto and in shaping its diverse surface morphology.

PHASE-MAGNITUDE DEPENDENCE OF HIGH-ALBEDO OUTLIERS IN PRIMITIVE ASTEROID FAMILIES

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Primitive asteroids are of particular importance for studies of the origin and early evolution of the Solar System because they are thought to preserve, to a large extent, the primordial material of the protoplanetary disk that has experienced only limited thermal and chemical alteration. These objects are generally associated with the carbonaceous taxonomic complexes (C, B, G, F), which are characterized by low geometric albedos and relatively neutral or moderately red reflectance spectra in the visible wavelength range. In recent years, interest in primitive asteroids has increased substantially following the return of samples from the near-Earth asteroids Bennu and Ryugu, which have provided unprecedented insights into the composition, mineralogy, and alteration history of carbonaceous material. Complementary observations with the JWST have revealed diagnostic spectral features of hydrated minerals and organic-bearing materials on primitive asteroids, opening new opportunities for linking remote sensing observations with laboratory analyses of returned samples.

Our study aims to improve the quality of the phase-magnitude dependences of asteroids with unusually high albedo in the largest primitive families (Themis, Hygiea, Pallas).

We developed a software pipeline that combines dense TESS photometry with sparse observations from the ZTF and ATLAS surveys. The TESS data are used to derive high-quality rotational lightcurves and determine the rotation period. In the absence of a reliable catalog period, the rotation period is estimated using a combination of the Lomb–Scargle periodogram, Fourier-series fitting with model selection based on the Bayesian Information Criterion, phase dispersion minimization, harmonic analysis of variance, and the conditional entropy method, with robustness assessed through bootstrap resampling. The resulting TESS lightcurve is then used to remove rotational modulation from the ZTF and ATLAS photometry. The corrected data are fitted with the HG1G2 phase-function model to refine the absolute magnitude and phase-function parameters and, where an independent diameter measurement is available, to derive the geometric albedo. To date, combined TESS and ZTF/ATLAS results have been obtained for 30 asteroids, yielding refined parameters of their phase-magnitude dependences.

RADIO ASTRONOMY

INITIAL RESULTS OF A WIDEBAND DECAMETER SURVEY OF THE GALACTIC BACKGROUND WITH THE URAN-2 RADIO TELESCOPE

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Studies of the Galactic background at decameter wavelengths provide crucial insights into the distribution of Galactic synchrotron radio emission, cosmic-ray electron propagation, and free-free absorption in the ionized interstellar medium. However, observations in this frequency range are severely hindered by ionospheric effects and strong radio-frequency interference. This report presents the initial results of a large-scale study of the Galactic background based on sky surveys conducted in 2023 with the URAN-2 radio telescope. The observational methodology and the data-processing pipeline are discussed. We present drift scans showing Galactic and extragalactic radio sources passing through the antenna beam, as well as large-scale Galactic structures and the Galactic background power as a function of right ascension.

THE PLANNED MULTI-ANTENNA COMPREHENSIVE SURVEY OF THE NORTHERN SKY ("UNIVER SURVEY"): FIRST RESULTS OF THE PILOT SURVEY WITH THE URAN-2 RADIO TELESCOPE

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In 2027 – 2031, a deep, statistically complete multi-antenna survey of the Northern sky is planned using the URAN system decameter instruments and the GURT decameter-meter radio telescope. The novelty of the proposed study lies in the simultaneous detection of all known types of cosmic radio emission and astrophysical objects of different classes within a single observational data set. The survey will be carried out simultaneously on all instruments in a coordinated manner by scanning the celestial sphere with fixed beams, taking advantage of the Earth's daily rotation, over the full range of right ascensions (0h – 24h) and declinations (−20° to +90°). The beams will be shifted by 4° in declination each day, resulting in a complete sky coverage cycle every 28 days. Accordingly, 12 complete cycles will be performed per year and 60 over a five-year period. Coordinated observations with five antennas operating simultaneously will increase the total number of cycles to 300. This approach will provide unprecedented sensitivity, improved RFI immunity, and enhanced measurement reliability.

Since April 2026, a pilot version of the survey has been conducted with the URAN-2 radio telescope. The aim of the pilot survey is to develop and validate the observing methodology, calibration procedures, and primary data-processing techniques. To date, three complete 28-day survey cycles have been completed (April, May, and July 2026). Corresponding test observations are also being carried out with the GURT radio telescope.

The first results of the pilot survey, including representative spectra and daily scans obtained at different declinations, will be presented. The observational methodology, data-processing procedures, and data-averaging techniques will also be described.

THE EFFECTS OF REGIONAL SEISMIC ACTIVITY ON THE SCINTILLATION CHARACTERISTICS OF COSMIC RADIO SOURCES IN THE DECAMETER WAVELENGTH RANGE

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The Earth's ionosphere significantly influences radio wave propagation along trans-ionospheric paths, which significantly determines the operating conditions of many ground-based and space-based radio systems. In particular, this applies to the URAN network of low-frequency radio telescopes of the National Academy of Sciences of Ukraine.

On the one hand, radio astronomical observations and data processing must take into account the interfering effects of the ionosphere. On the other hand, distortions in received signals carry information about the state of the ionosphere. The URAN-4 radio telescope monitors a group of powerful cosmic radio sources. Using the obtained data, it is possible to study ionospheric scintillations, which characterize the turbulence of the ionospheric plasma, which is affected by various external influences. One source of such influences is seismic

activity. Determining the quantitative dependence of ionospheric scintillations on seismic activity has both scientific and practical significance.

The URAN-4 radio telescope is located in the Odessa region, which has low seismic activity. The nearest seismically active region is approximately 300 km from the URAN-4 RT. This is the Vrancea zone (Romania), located at the junction of the Southern and Eastern Carpathians. This paper examines the influence of seismic activity in the Vrancea zone on the characteristics of ionospheric scintillations.

SINGLE TYPE III BURSTS AS A DIAGNOSTIC INSTRUMENT OF SOLAR CORONA

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Observations of Type III bursts in the wide frequency band from hectometer to decameter wavelengths allow studying properties of solar coronal plasma from 1-2 to tens of solar radii. On the example of the single Type III burst observed in the frequency range of 0.3-19 MHz by PSP, we show that analyzing drift rate dependences on frequency of different levels of this burst allow finding density-distance dependences. According to frequency ranges of 5-19 MHz, 1.2-5 MHz and 0.3-12 MHz there were three space regions: 1.9<R/R_S<3.1, 3.1<R/R_S<9.3 та 9.3<R/R_S<31, in which the density of coronal plasma changed as 1.55·10^8 〖·R〗^(-5.5) 〖cm〗^(-3), 5.9·10^6 〖·R〗^(-2.6) 〖cm〗^(-3) and 3·10^6 〖·R〗^(-2.3) 〖cm〗^(-3) during propagation of electrons that generated this Type III burst. We explain these dependences as a solution of corresponding hydrodynamics equations in the case of plasma non-isothermality. We also find variations of plasma temperature at different distances.

SIMILAR CHARACTERISTICS OF OPTICALLY UNIDENTIFIED AND IDENTIFIED RADIO SOURCES WITH STEEP LOW-FREQUENCY SPECTRA

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In the UTR-2 catalog of extragalactic sources, approximately half of the objects with steep low-frequency spectra have not optical identifications. Like the identified steep-spectrum sources, the galaxies and quasars from the UTR-2 catalog exhibit two types of low-frequency spectra: a steep linear spectrum (type S) and a steep spectrum with a break (type C+). From the sample of galaxies and quasars and the sample of optically unidentified sources with steep radio spectra, we obtained similar spectral index values for each spectral type. The distribution of the ratio of source radiation flux densities at frequencies of 25 MHz and 5000 MHz revealed maxima for galaxies and quasars as well as for unidentified sources. Moreover, for sources with steep C+ spectra, two maxima are observed in the distribution of the Log(S25/S5000) ratio, which may indicate cyclical activity in these sources.

ALGORITHMS FOR PROCESSING LOW-FREQUENCY RADIO ASTRONOMICAL SIGNALS UNDER CONDITIONS OF SHORT-TERM INTERFERENCE

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The development of antenna array technology and signal processing hardware in radio astronomy has enabled observations in very wide frequency bands, which are often covered by out-of-band emissions from television transmitters, communications systems, navigation systems, and other terrestrial sources. Radio astronomy shares most of these bands with active services that transmit signals for various purposes. Algorithms for compensating for short-term interference for radiometry and radio interferometry systems are proposed. Software for signal reception using the FOBOS SDR wideband receiver and subsequent signal processing in the Matlab environment was developed. A comparative analysis of the effectiveness of adaptive interference suppression algorithms operating in the time and frequency domains is conducted. Requirements for the training sample size of interference are determined when adapting radiometry systems to suppress short-term interference with an unknown spectrum shape. It is shown that the proposed algorithms enable suppression of correlated short-term interference to the level of the receiving system's internal noise.

METHOD OF MULTI-ANTENNA STUDY OF RADIO SOURCE SCINTILLATIONS IN THE URAN INTERFEROMETER NETWORK

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Observations of radio source scintillations caused by electron-density inhomogeneities allow the study of Earth's ionosphere and interplanetary plasma along the propagation path of signals from the emitter to the radio telescope. Measuring the scintillation index and determining the scintillation spectrum using a radio telescope make it possible to estimate the degree of turbulence in the medium and the parameters of its inhomogeneities. Multi-antenna observations of scintillations also enable the determination of their velocity vectors.

The radio telescopes of the URAN network have frequently been used to study scintillations at decameter wavelengths. The UTR-2 and URAN-2, with the largest effective area, sensitivity, and spatial selectivity, are the most convenient, allowing the use of radio sources with relatively low flux densities for observations. Similar studies were also widely carried out with the URAN-1 and URAN-4 radio telescopes; however, the small collecting areas of their antennas made it necessary to use only the most powerful radio sources for probing the medium. In these studies, the radio telescopes of the network generally operated as standalone instruments.

Scintillation studies can be conducted in the URAN interferometric mode simultaneously with the investigation of radio source structures. The use of multiple antennas increases the amount of information obtained. For this purpose, we have developed a method for analyzing the interferometric response across different baselines to determine scintillation parameters at each network site. This method does not require the use of independent radiometers at each site. It features increased sensitivity, spatial selectivity, and interference immunity, which allows its application in observations of faint radio sources. The report discusses the advantages and limitations of the method and presents examples of its application.

STUDY OF CSS RADIO SOURCES AT DECAMETER WAVELENGTHS USING THE URAN INTERFEROMETERS

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Compact Steep Spectrum (CSS) sources are radio galaxies with small angular sizes. Their linear dimensions are typically smaller than the host galaxy's diameter. They are generally believed to represent an early evolutionary stage of extragalactic radio sources associated with galactic nuclear activity. Observations at decameter wavelengths with the URAN interferometers have often revealed extended structural components in radio galaxies that are not detected at shorter wavelengths. To search for such components in the most powerful CSS sources from the 3C catalog, we observed ten radio galaxies of this type using the URAN interferometric network. An increase in the apparent sizes of the most compact CSS sources was detected, caused by radio-wave scattering on electron density irregularities in the interstellar medium. The magnitude of this effect depends on the Galactic coordinates of the sources. For several radio galaxies, the interferometric response measured on the longest URAN baselines was significantly lower than the values predicted from high-frequency radio maps, even after accounting for the additional source broadening due to scattering. This discrepancy can be explained either by the presence of extended structural components that become prominent at decameter wavelengths or by regions of anomalously strong scattering, particularly for sources located near the Galactic plane.

IDENTIFICATION OF CORONAL ALFVÉN WAVES IN GURT RADIO TELESCOPE DATA

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In this report, we present the evidence for the first identification of coronal Alfvén waves based on observations performed with the GURT radio telescope on 21 May 2024 in the frequency range of 8–80 MHz. On that day, a compact group of solar radio bursts, including Type III, Type IIIb, U bursts, and spikes, was recorded. Among these bursts, we identified three previously unobserved bursts. Spectral analysis revealed that these bursts consist of sub-bursts which were quasi-periodically distributed in the dynamic spectrum and were confined within the envelope of the main burst. In contrast to typical meter-decameter Type IIIb bursts the fine structure of newly registered bursts have a positive drift rate averaging 0.47 MHz/s and almost constant spacing between adjacent sub-bursts of about 0.5MHz. The analysis of the spectral properties of the sub-bursts provided the following parameters: the apparent velocity of the emission source is about 1.4 Mm/s; the spatial separation between emission maxima approximately 1.5 Mm; the repetition rate of the emission is 0.9 Hz. The velocity, spatial separation between the sub-bursts and the repetition rate are close to the speed, wavelength and the frequency of Alfven waves observed in the optical range. This similarity suggests that Alfven wave may play an important role in formation of the fine structure of such unusual bursts.

DIAGNOSTICS OF PLASMA PARAMETERS INSIDE AND OUTSIDE THE CME CORE USING DECAMETER

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A comparative diagnosis of the CME core and the surrounding corona plasmas using the properties of decameter radio spikes observed by UTR-2 radio telescope on 22 August 2015 is presented. The spikes were observed during a complex solar radio event both as a fine structure of a Type IV burst and as part of Type III-IIIb bursts storm that occurred after the end of the Type IV burst. The analysis of the spikes parameters showed that the bursts being the fine structure of the Type IV burst

have durations that are, on average, 1.7 times longer than those observed during the subsequent Type III-IIIb storm, whereas their bandwidths are practically the same. Using these parameters, the plasma properties inside the CME core and in the surrounding corona were estimated. As a result, the plasma temperature inside the CME core was found to be approximately 1.7 times higher than that in the surrounding corona (0.46 MK versus 0.26 MK), whereas the magnetic field strength remained nearly unchanged (1.5 G and 1.3 G, respectively).

IMPACT OF COMBAT OPERATIONS IN UKRAINE ON THE ECOLOGY OF THE EARTH'S NORTHERN HEMISPHERE BASED ON MONITORING OF MESOSPHERIC CARBON MONOXIDE (CO)

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About a year after the Russian Federation launched its full-scale invasion of Ukraine, scientific publications began to appear detailing the deterioration of ecological conditions in various parts of our country. These studies focused on observed environmental degradation in the near-surface layer of the atmosphere and were linked to rising concentrations of harmful substances such as NO_2, CO, SO_2, SO_4, and aerosols.

Since 2017, the Radio Astronomy Institute of the National Academy of Sciences of Ukraine has been monitoring stratospheric carbon monoxide (CO) based on its microwave radiation at the frequency of 115 GHz. This radiation is emitted by CO molecules located at altitudes of 70–90 km. The main objective for which the monitoring system had been developed is to obtain information about atmospheric parameters at these altitudes. Carbon monoxide was used as an indicator gas. At the same time, the system made it possible to determine the number of CO molecules and analyze their dynamics.

Monitoring revealed seasonal variability in the number of stratospheric CO molecules. In winter, there were approximately three times as many as in summer. Therefore, to identify long-term trends in stratospheric CO, it is necessary to compare the average number of molecules per season. It should be noted that in winter, there are polar vortices that can persist for up to several months. These vortices form because, between 30 and 65 degrees north latitude, the Ferrel circulation cells and the polar circulation cell converge. As a result, stratospheric air masses are effectively mixed, and by monitoring the concentration of a trace gas, information is gathered about virtually the entire stratosphere of the Northern Hemisphere.

The analysis of nearly 10 years' worth of data on stratospheric CO—recorded daily during monitoring—provides grounds to conclude that its concentration has increased significantly since the start of combative operations in Ukraine. According to our estimates, the increase was 30% during the winter months and 40% during the summer months. This finding correlates with the fact that the intensity of combat operations is higher in the summer than in the winter.

Carbon monoxide is one of the most harmful gases, significantly degrading the ecological environment. The increase in CO levels in the stratosphere—where air masses mix intensively—indicates that the prolonged combat operations in Ukraine, as well as retaliatory strikes against Russia, are significantly worsening the ecological situation across virtually the entire Northern Hemisphere. Not only Ukraine suffers from this environmental degradation, but also Canada, the United States, and European countries—including the aggressor itself.

DIGITAL ARCHIVE OF HISTORICAL ANALOG OBSERVATIONS FROM THE RT URAN-4 (IRA NASU) OF POWERFUL RADIO SOURCES DURING SC 22 (1987-1993)

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Since its launch in 1987, the URAN-4 radio telescope has been monitoring powerful radio sources, including the remnants of the supernovae Cassiopeia A and Taurus A (3C461, 3C 144) and the radio galaxies Cygnus A and Virgo A (3C405, and 3C274) at frequencies of 20 and 25 MHz as they pass through a directional pattern at intervals of 40 or 60 minutes two hours before and after the culmination. A significant volume of data from the URAN-4 radio telescope, recorded between 1987 and 1993, is still preserved exclusively on paper media. This precludes its processing with modern software tools and limits access to valuable historical data. The objective of this work is to establish a digital archive of these records and convert them into a digital format. The process of creating the digital archive was divided into several stages: a comprehensive inventory of the paper records; the creation of an electronic catalog containing basic information about each record (dates, polarization, frequency, objects, and the physical condition of the paper media); and the initiation of systematic scanning of the paper records followed by their digitization. The results of the scanning and digitization processes are stored in an internal database. Establishing this digital archive not only rescues historical data from physical degradation but also enables the retrospective analysis of long- and short-term variability of radio sources and ionospheric effects using modern computational methods. To date, using the compiled database of digitized records, two papers have been written regarding the magnetic storms of 25-30 April 1989 and 19-23 October 1989.

RADIATION OF ULTRARELATIVISTIC ELECTRONS MOVING IN CURVED MAGNETIC FIELD LINES: SYNCHRO-CURVATURE RADIATION

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We present general radiation formulas for ultrarelativistic charged particles moving into curved magnetic field lines, taking into account the curvature of magnetic field. The particle trajectory has the form of a curved helix. The power, angular distribution, spectral distribution and polarization properties of the radiation are obtained. At critical limits, the formulas transform into the formulas for synchrotron radiation or curvature radiation. If the velocity of centrifugal drift is of the order of the Larmor rotation velocity, then it is necessary to use the presented formulas for the synchro-curvature radiation. We compare our formulas with those in literature by other authors. The conditions for the applicability of this radiation mechanism in cosmic sources are considered.

COORDINATED LOW-FREQUENCY OBSERVATIONS OF CASSIOPEIA A AND SCINTILLATION DIAGNOSTICS

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Simultaneous low-frequency observations of Cassiopeia A with NenuFAR (France) and URAN-2 (Ukraine) on 6-9 July 2025 reveal correlated scintillation signatures across a 2000 km baseline. Both observatories recorded dynamic spectra during source tracking and cross-correlated the signals to diagnose the origin of fluctuations. The analysis shows synchronous, broadband variations consistent with interplanetary scintillation (IPS), while episodes of decorrelated variability indicate ionospheric scintillation (IS). IPS signatures are detected at both sites; at NenuFAR they are partially masked by strong IS, whereas at URAN-2 the IPS component dominates. By combining dual-site radio measurements with contemporaneous solar wind and interplanetary magnetic field parameters from the NASA/SPDF OMNI dataset, we establish a reproducible framework for separating IPS from IS. This coordinated campaign demonstrates the diagnostic power of multi-site experiments and provides a benchmark for future investigations of solar wind turbulence and space weather at low radio frequencies.

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DECADAL FLUX DENSITY STABILITY AND MAGNETOHYDRODYNAMIC EQUILIBRIUM IN THE SUPERNOVA REMNANT IC 443: NEW INSIGHTS FROM NENUFAR

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The evolutionary dynamics of mature supernova remnants (SNRs) interacting with dense interstellar environments remain a cornerstone of cosmic ray acceleration and magnetohydrodynamic (MHD) studies. In this work, we present a comprehensive multi-wavelength study of the middle-aged SNR IC 443 (the Jellyfish Nebula, 3C157), linking long-term flux density monitoring with a self-consistent physical model of its absorbing medium.

First, we utilize recent ultra-low frequency observations obtained with the NenuFAR radio telescope, combined with a compiled historical continuum dataset spanning more 70 years, to evaluate the temporal evolution of the remnant's radio spectrum. We demonstrate that within the 10-10 000 MHz range, the integrated flux density of IC 443 exhibits remarkable long-term stability. Accounting for NenuFAR's ~6 % observational precision, any secular variations are strictly constrained to less than 0.1 % per year, implying a virtually static synchrotron emission regime.

Second, we provide a robust physical explanation for this temporal invariance. By analyzing the low-frequency radio spectral turnover, we show that the modulation is entirely governed by free-free absorption within a cold ($T_e \approx 10^4$ K) photoionized boundary layer formed at the collision interface with the adjacent giant molecular cloud. A statistical nested F-test heavily favors a two-parameter pure foreground screen model ($\chi^2 = 1.086$), which converges to an unattenuated normalization flux density $S_0 = 928 \pm 11$ Jy and an external optical depth $\tau_{ext} = 0.986 \pm 0.144$ at 10 MHz, while rendering the internal absorption strictly negligible.

By coupling these empirical constraints with independent Zeeman-splitting measurements ($B \approx 600$ μG), we establish that this partially ionized interface is in strict MHD equilibrium, characterized by a bulk plasma parameter $\beta \approx 1.2$. This near-unity beta constraint delivers a novel physical conclusion: the amplified magnetic field provides the critical dynamic confinement necessary to stabilize the overdense filaments against rapid acoustic dissipation into the lower-density interior cavity. This

magnetic encapsulation effectively isolates the absorbing medium from the turbulent interior, ensuring the macroscopic and spectral longevity of IC 443 over macro-evolutionary timescales.

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SOFTWARE TOOLS FOR THE AUTOMATED ANALYSIS OF IONOSPHERIC SCINTILLATIONS OF COSMIC RADIO SOURCES FROM URAN-4 RADIO-TELESCOPE OBSERVATIONS AND GEOMAGNETIC VARIATIONS FROM THE "INTERMAGNET" NETWORK DURING GEOMAGNETIC STORMS

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Automated software for the analysis of geomagnetic time series and ionospheric scintillation data opens new opportunities for integrated studies of solar–terrestrial coupling. Geomagnetic observations from the INTERMAGNET network provide high-precision recordings of magnetic-field variations, including ULF pulsations that reflect the dynamics of upper-atmospheric current systems and resonant processes in the magnetosphere. At the same time, decameter-band observations from the URAN-4 radio telescope capture ionospheric scintillations of cosmic radio sources, which are sensitive to small-scale plasma structure and its turbulence. Integrating these two data types requires robust algorithms for preprocessing, filtering, time–frequency analysis, and automatic event detection. Software tools designed for processing large sets of files make it possible to analyze wavelet spectra of magnetometric and radio-astronomical time series, isolate characteristic bands of pulsation and scintillation periods, and identify correlations between radio frequencies and different geomagnetic observatories. The use of modern machine-learning methods and wavelet analysis increases the accuracy of event classification and enables the detection of weak signals previously hidden in noise. The developed software forms a foundation for reproducible space-weather research, simplifies the workflow for investigators, and provides a unified tool for analyzing large volumes of data. This approach contributes to a deeper understanding of magnetosphere–ionosphere interactions and improves diagnostics of processes that affect technological systems and radio communication. The report presents the results of developing Python-based software for analyzing the geomagnetic storm of 15–16 May 2026 (in the region of the historical "Struve Geodetic Arc") and for examining the structure of ionospheric scintillations observed in January 2013.

CHARACTERISTICS OF COSMIC-RADIO-SOURCE SCINTILLATIONS DURING GEOMAGNETIC STORMS BASED ON DECAMETER-BAND IONOSPHERIC PROBING OBSERVATIONS FROM THE LOFAR LV614 TELESCOPE (IRBENE, LATVIA) AND URAN-4 (ODESSA, UKRAINE)

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Ionospheric scintillations in the decameter band (10–30 MHz), observed with the LOFAR LV614 and URAN-4 telescopes, acquire distinct properties during geomagnetic storms, because geomagnetic disturbances substantially modify plasma structure in the F and E layers. Since 2022, the URAN-4 radio telescope, in collaboration with the Institute of Geophysics of the NAS of Ukraine, has been monitoring geomagnetic field disturbances. Since 2026, the Irbene Observatory has become the first in Latvia to continuously record geomagnetic field disturbances at the site of its radio telescopes. The intensification of currents in ionospheric conductive layers, the emergence of additional irregularities, and increased turbulence lead to stronger refraction and scattering of radio waves. As a result, scintillations become deeper, faster, and spectrally more complex, making them a sensitive indicator of space-weather dynamics. Observations at mid-latitudes—such as in Ukraine and Latvia—are of particular interest, since the ionosphere in these regions is influenced both by moderate geomagnetic disturbances and by periodic intrusions of high-latitude effects. Here, scintillations reflect subtle changes in plasma distribution that are difficult to detect by other methods. Studying their properties refines ionospheric-turbulence models, helps assess the impact of geomagnetic storms on radio systems, and reveals connections between large-scale magnetospheric processes and local ionospheric structures. This work examines the properties and distinctive features of ionospheric scintillations during geomagnetic disturbances of varying intensity in the region of the Odessa Magnetic Anomaly (URAN-4) and in the more northern site of Irbene, Latvia (LOFAR LV614). For URAN-4 data, two period bands—10–150 s and 150–600 s—were extracted, and cross-spectral wavelet analysis was performed between the 20 MHz and 25 MHz channels. Collapsing the LOFAR dynamic spectrum into a "periodogram," where the Y-axis contains the observing frequencies (e.g., 30–60 MHz) and the X-axis contains the variation periods derived from FFT time series for each frequency, provides quite important diagnostic information about the structure of

ionospheric processes. These data are valuable both for fundamental research and for applied tasks in radio communication and space-weather monitoring.

ON THE MECHANISMS OF FORMATION OF RADIO STORMS AND DAM RADIO BURSTS IN THE JUPITER'S MAGNETOSPHERE

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There are investigated the mechanisms of storm formation and burst activity of DAM radio emission in the magnetosphere of Jupiter, such as Io-dependent DAM radiation and non-Io DAM/HOM radiation. The model considered here takes into account the influence of Io-Jupiter Alfven turbulence and atmospheric storms with thunderstorm activity on the plasma transport to the lower magnetosphere region and on the development of the maser generation processes of the DAM radio sources.

It is shown that the power of DAM radiation from sources is proportional both to the electron density and the power of Alfven turbulence in active regions. These sources are located at the altitudes of approximately 0.01-0.5 Rj for Io-dependent DAM radio emission, and at altitudes of 0.3-2 Rj for non-Io DAM/HOM emission. To explain the observed DAM radio emission powers of 10^6-10^7 Jy, the plasma density at these altitudes should increase to 10^5 cm-3 within the auroral ovals, and to 10^4 cm-3 in high-latitude polar regions. The Alfven turbulence can create the magnetic field fluctuations of up to 0.1 G, with periods of about 300 s, and will support plasma transport from the Io torus to Jupiter poles, with Alfven currents of along Jupiter's magnetic field lines, interacting with active-stormed atmosphere.

The Jupiter's polar regions thunderstorm activity creates the powerful electric fields (>100 V/m) and discharges bursts, ejecting electrons into Jupiter's magnetosphere, modulating the DAM emission in S-bursts of 2-5 ms. These processes are accompanied by the streamers elongating in magnetosphere, may generating plasma waves, which are then transformed into tX-waves (with the possible participation of whistlers). The transport of the tX-wave packets through the magnetospheric plasma activated by MHD turbulence is accompanied by their maser amplification in directions of the DAM emission cone.

STUDY OF RADIO ABSORPTION FEATURES DETECTED IN NORTHERN SKY SURVEYS AT 0° DECLINATION USING THE UTR-2 AND URAN-2 RADIO TELESCOPES

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This report presents the results of a survey covering the entire right ascension range (0h – 24h) at 0° declination in the continuum and in decameter carbon radio recombination lines (RRLs). During the analysis of time-series scans from observations carried out in January – February 2022 with the West – East antenna of the UTR-2 radio telescope, an unusual absorption region in the Galactic non-thermal background was detected near a right ascension of 18h25m. This region is not spatially associated with any known Galactic H II regions. Preliminary analysis suggests that the observed background absorption is caused by cold interstellar plasma. The results of carbon RRLs observations of this region are presented. The characteristics of the detected lines inside and outside the absorption region are compared. Additional observations obtained with the URAN-2 radio telescope in 2023 at 0° declination are also included in the analysis.

UNUSUAL FLARING ACTIVITY IN ACTIVE GALACTIC NUCLEI: LINKING RADIO-MORPHOLOGY AND LIGHT CURVES OF BBH CANDIDATES

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The search for supermassive binary black holes in active galactic nuclei is one of the most pressing challenges in modern astrophysics. However, confirming their existence in specific cases remains quite difficult. Candidate binary systems typically exhibit powerful outbursts and flares across a wide range of wavelengths, which often correlate with distinct changes in their radio morphology.

This paper compares broadband optical and radio light curves against VLBI-derived jet kinematics. Position angle dispersion metrics and time-position diagrams are utilized to quantitatively assess jet stability, and investigate its correlation with optical and radio activity.

The example of one of the clearest candidates for binary black hole systems (the blazar OJ 287) demonstrates a correlation between powerful optical flares – associated with companion's intersections of the main accretion – and subsequent radio flares linked to jet destabilization, manifested as an abrupt increase in dispersion. This behavior is compared to that of the second binary candidate, the blazar 3C 454.3, and the relatively calm BL Lac. This flare-morphological connection is proposed for further verification as a metric for binary BHs searching in active galactic nuclei.

SOLAR ACTIVITY, SOLAR-TERRESTRIAL RELATIONS, ASTROBIOLOGY

MICROWAVE SPECTRAL POLARIMETRIC OBSERVATIONS OF THE SUN IN LATVIA

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It is known that observations of microwave (1-10 cm) polarized emission of the Sun offer the possibility for a direct measurement of plasma parameters and magnetic field inductions in the upper chromosphere and the lower corona. It is also known that different wavelengths of microwaves are emitted at clearly defined heights above the photosphere depending on mechanisms of the emission. Thus, spectral microwave observations of the Sun allow to study the structure of a solar atmosphere in some range of heights simultaneously. In this sense spectral polarimetric observations of the solar microwave emission could be expected for a wide range of solar physics problems understanding solar activity features and origins of the space weather creation.

For a couple of years Ventspils International Radio Astronomy Centre (VIRAC) of Ventspils University of Applied Sciences, Latvia, develops and performs spectral polarimetric microwave observations of the whole disk of the Sun and its separate active regions. Observations are performed with the RT-32 radio telescope in a "single dish" mode. For this purpose, the radio telescope was equipped by the multichannel (12 frequency channels) spectral polarimeter, the data acquisition system and data pipeline. The whole solar observational system provides an automatic observations and measurements of the solar emission at 2.1-7.4 cm (4.1-14.3 GHz) wavelength range and both circular polarizations simultaneously. The presentation concerns to a current state solar microwave observations in VIRAC, its technical and methodical issues and some projects VIRAC participated in. Also, the presentation discusses feasible problems of solar physics which could be solved on the base of these microwave spectral polarimetric observations. The possibilities of the coronal magnetography are shown. Problems of a quiet Sun determination and a detection of coronal holes and coronal hole-like areas associated with local open magnetic fields are presented and discussed. The analysis of microwave flux fluctuations of active regions preceding solar flares are discussed as well.

VIRAC INTERNATIONAL COLLABORATIONS IN SOLAR AND SPACE WEATHER RESEARCH: FROM SOLAR RADIO OBSERVATIONS TO IONOSPHERIC MONITORING

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The VIRAC significantly expanded its role in international solar and space weather research through participation in several collaborative scientific initiatives that combine radio astronomy, solar physics, ionospheric studies, and advanced data-analysis techniques. VIRAC operates the 32-m radio telescope RT-32 and the LOFAR-Latvia (LV614) station, providing unique observational capabilities for both solar and geospace investigations.

VIRAC's solar physics activities include routine multi-frequency microwave observations of the Sun, monitoring of coronal holes, active regions, and other radio manifestations of solar activity using the RT-32 telescope and dedicated spectral polarimeters. Recent studies have demonstrated the capability of VIRAC facilities to detect and characterize coronal holes throughout Solar Cycle 25, providing valuable information on open magnetic-field regions and potential sources of high-speed solar wind streams associated with space weather disturbances.

A significant part of VIRAC's current research is conducted within the framework of the Latvian Science Council project FLARE, focused on developing novel observational proxies and data-driven approaches for solar flare forecasting, and the STEF project carried out in collaboration with the University of Warwick, UK. These projects combine radio observations, machine-learning methods, and international scientific cooperation to improve our understanding of flare triggering mechanisms and short-term flare prediction. Recent research performed within these collaborations includes studies of flare morphology, time-domain anomalies, magnetohydrodynamic wave processes, coronal seismology, and new spectral diagnostics of solar activity.

In 2026, VIRAC launched the IONEX project (*Characterisation of Extreme Space Weather Effects on the Ionosphere*), bringing together research groups from Latvia, Finland, and Ukraine. The project utilizes observations from LOFAR-Latvia, the KAIRA array, the URAN-4 radio telescope, geomagnetic observatories, and cosmic-ray detectors to investigate ionospheric scintillations, geomagnetic disturbances, and regional manifestations of space weather along the historic Struve Geodetic Arc. Interest is devoted to the effects of geomagnetic anomalies and extreme solar activity on ionospheric dynamics and radio-wave propagation.

MAGNETIC FIELD DIAGNOSTICS IN A SUNSPOT USING DIGITAL SPECTRAL-POLARIZATION OBSERVATIONS OF METAL LINES

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We present the results of magnetic field diagnostics in a large sunspot, which was observed on the horizontal solar telescope of the Astronomical Observatory of the Kyiv

National University on May 2, 2025, in the NOAA 4079 group. The I ± V spectra of this sunspot were recorded using a Sony NEX-5 digital camera in diffraction orders 36-38 of the Echelle spectrograph. The magnetic fields were measured by the Zeeman splitting of 17 spectral lines Fe I, Cr I, Mn I, Ni I and Ti I, which have effective Lande factors g_{eff} from -0.012 to 2.143 and the heights of formation of their centers in the sunspot umbra from 47 to 453 km. The following main effects are found: (1) in the height range of 50-450 km, the magnetic field has a negative height gradient of about -1.4 G/km; (2) the magnetic fields by the FeI 5434.5 and FeI 5576.1 lines with the smallest Lande factors (-0.014 and -0.012, respectively) have similar lateral profiles across the spot and reach intensities of 6-8 kG, which is significantly higher in absolute value than by other spectral lines with larger Lande factors. Such super-strong magnetic fields by these FeI lines with very small Lande factors mostly have the S-polarity, opposite to the N-polarity of the magnetic field by other spectral lines. This indicates that the magnetic field structure in the spot was at least two-component, with a weaker background component and a stronger small-scale (spatially unresolved) component, which had a local strengths, probably greater than 6-8 kG. We also found evidences to weak splitting of the bisectors of the I ± V profiles at distances of 0.2-0.3 Å from the centers of the FeI 5434.5 and FeI 5576.1 lines, which may indicate the gigantic magnetic fields of the Mega-gauss range.

ON THE POSSIBLE INFLUENCE OF SOLAR ACTIVITY ON THE OCCURRENCE OF ANOMALOUS WEATHER PHENOMENA

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This study attempts to find the cause of the abnormally cold January 2026 in Ukraine under the influence of solar activity. For this purpose, the average monthly values of air temperature (the website of the Central Geophysical Observatory named after Boris Sreznevsky www.cgo-sreznevskyi.kiev.ua) and solar activity (the website of the Space Weather revised series of relative Wolf numbers of the International Data Center of the Royal Observatory of Belgium www.swpc.noaa.gov) were used for the period 1880-2025.

The data of measurements of magnetic fields in sunspots for the last few years were also used. The main results are as follows:

(1) Over the past 145 years, a significant increase in temperature in Kyiv has been observed, with a trend increase of approximately 4 degrees. However, against the background of this trend, significant deviations from the average value (i.e. anomalies) are observed, which for January temperatures reach 9 degrees.

(2) For January temperatures in Kyiv over the past 145 years, 5 cases were found when negative temperature anomalies coincided with an accuracy of 1-2 years with the beginning of the 22-year Hale cycle – the cycle of changing the polarity of magnetic fields in sunspots.

(3) For the average annual temperatures in Kyiv for 2022-2025, a positive correlation was found between the anomalies of these temperatures and deviations from the average value of magnetic field strengths in large sunspots with a diameter in the range of 22-44 Mm. The latest data were used based on the results of measurements of the magnetic field in sunspots on the horizontal solar telescope of the AO KNU. If this correlation persists, there should be a small positive anomaly of the annual temperature in 2026 (by 1-2°C), since in the first half of 2026 there is a slight increase in the magnetic field intensities in sunspots relative to the average value in recent years.

CHROMOSPHERIC MAGNETIC FIELD DIAGNOSTICS IN A SUNSPOT USING THE H-ALPHA LINE BISECTORS

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Magnetic fields in solar chromosphere have been studied much less than in the photosphere. In particular, there are no direct data on the magnetic field strength modulus for the chromosphere. For this purpose, we studied the I + V and I – V profiles of of the H-alpha line in the spectrum of a sunspot observed on July 17, 2023 on the Echelle spectrograph of the horizontal solar telescope of the Astronomical Observatory of the Taras Shevchenko National University of Kyiv. According to visual measurements using the Fe I 5250.2 line (g = 3.0), the photospheric magnetic field in this sunspot reached 2870 G, its polarity was N. The sunspot spectrum was photographed on an ORWO WP3 photographic plate and scanned with an Epson Perfection V 550 scanner. The methodology for processing the corresponding scanograms to obtain quantitative scientific information is presented in the article at the following link: https://doi.org/10.1093/mnras/stad1816.

We found that splitting of bisectors of the I + V and I – V profiles of the H-alpha line turned out to be unequal in different parts of the line profile; it mostly increased when moving from the wings of the line to its core. At the same time, for some areas of the sunspot, the maximum splitting of the bisectors in the core of the line corresponded to magnetic fields of more than 3000 G, i.e. even stronger than at the photospheric level. Also, theoretical calculations within the framework of the Unno theory (1956) indicate that a similar appearance of the bisectors is possible only at very strong fields, which sometimes exceed 10 kG. Some details and the validity of this conclusion are planned to be discussed during the report.

STRANGE SOLAR ACTIVE REGION NOAA 14478

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On June 25, 2026, one of the largest active regions in recent times, NOAA 14478, appeared in the southern

hemisphere of the solar disk. It had a very large maximum area of 1550 millionths of the solar hemisphere (m. s. h.), many spots, including δ-spots. The magnetic structure of the region was very complex. Such regions typically produce very intense flares and powerful coronal mass ejections, which can even cause extreme magnetic storms. However, NOAA 14478 turned out to be surprisingly quiet and, contrary to predictions, did not produce a single X-class flare during its passage across the disk.

We have analyzed the evolution, changes in the structure of the magnetic field, and the flare productivity of the active region NOAA 14478, as well as the neighboring active regions NOAA 14475, 14477, 14479 and 14480 with which it was connected by magnetic field lines, for comparison. The active region NOAA 14478 developed rapidly. Its sunspot area increased from 350 to 1550 m. s. h., and the number of sunspots from 9 to 45. Starting on June 26, a complex multipolar magnetic field configuration of the Hale class βγδ with δ-spots was observed in this region. Typically, the appearance of δ-spots significantly increases flare activity, but weak flares occurred in this region, and it was not until July 1 that an M-class flare occurred. In total, it produced five M-class flares and 43 C-class flares.

NOAA 14479 was the largest in area and sunspot number among the neighboring active regions. It also rapidly expanded in size. Its maximum area and sunspot number were 720 m. s. h. and 35, respectively. Its magnetic field structure became increasingly complex. Beginning on June 30, it exhibited a βγδ configuration. During their transit across the disk, this region produced 32 M-class flares, 56 C-class flares, and one X-class flare. The remaining regions occupied a maximum area of no more than 250 m. s. h. and had a simpler magnetic structure of the β-βγ class. In total, active region NOAA 14475 produced 46 C-class flares and two M-class flares, NOAA 14477 produced six C-class flares, and NOAA 14480 produced six C-class flares and three M-class flares during their transit across the disk. On June 30, an interesting phenomenon was observed on the Sun: three flares one after another in rapid succession in the regions 14477-14475-14479, however, this did not affect the active region 14478 connected with these regions. The most powerful flare of class M5.9 occurred in active region 14475. On the same day, a flare of class X1.1 occurred in region 14479. Radiation from this flare ionized the upper layers of the Earth's atmosphere, causing a short-term attenuation of shortwave radio signals over North America and the Pacific Ocean. A coronal mass ejection from it collided with the Earth's magnetic field on July 3 and caused a geomagnetic storm of category G3. On July 1, several M-class flares occurred in active region 14479, and an M8.5 flare occurred in region 14478. These flares caused new coronal mass ejections directed toward Earth, which continued the geomagnetic storm. On July 4, the storm peaked with a Dst index of -150 nT. Beginning on July 3, the tail of sunspot group 14478 began to disintegrate, and the number of sunspots significantly decreased. Three more M-class flares occurred in this region. On July 8, it passed beyond the solar disk.

THE ROLE OF FLARES IN HEATING THE SOLAR CHROMOSPHERE AND CORONA

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Solar flares are formations on the surface of the Sun that frame active areas and whose brightness increases from the center to the edge of the solar disk. These formations are believed to be a set of magnetic tubes about a hundred kilometers in size and with magnetic field strengths of up to 1–2 kGs. Flares can make an additional contribution to the overall solar radiation, which can lead to a change in the Earth's climate.

Finding the reasons for the increased brightness of flares can be useful in solving the most pressing problem of solar physics, namely, understanding the mechanisms of heating the chromosphere and corona.

We analyzed the properties of wave movements in one of the observation flare areas and found out their role in heating these formations. The observations were made with the VTT telescope of the Institute of Astrophysics in the Canary Islands simultaneously in three spectral bands: spectropolarimetric in the FeI iron lines (1564.8 nm, 1565.2 nm); filter in the BaII line (455.4 nm) and filter in the CaII line (396.8 nm).

We believe that the increase in contrast with the increasing power of wave oscillations that occurs in bright areas of the flare may indicate the ability of wave motions to actually increase the temperature of these flare areas.

TURBULENT DYNAMO OF SOLAR MAGNETIC CYCLE

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Observations show that the poloidal and toroidal components of the Sun's global magnetic field cyclically change in magnitude and polarity in antiphase with a period of about 22 years, called the Hale magnetic cycle. There is now a near consensus among researchers that the Sun's magnetic cycle should be explained by the inductive action of hydrodynamic motions of an electrically conductive fluid penetrating deep subphotospheric layers (the hydrodynamic dynamo concept). Intensive theoretical and observational studies have led to the establishment of a baseline scenario for the solar dynamo, the identification of key dynamo parameters, and the formulation of a theoretical and methodological model of the nature of solar cyclic magnetism. Dynamo theory provides all the necessary tools and justification for finding an acceptable explanation for cyclicity of solar global magnetism. Most often, researchers use the αΩ dynamo model, which describes the magnetic cyclicity of the Sun due to two basic effects in the solar convective zone (SCZ): (1) generation of the toroidal field due to the action of differential rotation on the poloidal field (Ω effect) and (2)

the inverse transformation of the toroidal field into new poloidal field of the opposite orientation due to helical turbulent convective motions (α effect). This new poloidal field is necessary for the feedback of the two global magnetic components. So, it is the revolutionary α effect that plays a key role in the turbulent αΩ dynamo model, since it allows the solar cycle to be closed, which was lacking in laminar dynamo models.

Studies in the last half century have shown that the physical conditions in the depths of the SCZ are favorable for the αΩ dynamo mechanism, which in the kinematic mode quite adequately describes the dynamics of the Sun's magnetic cycle. However, a number of observed magnetic phenomena have remained unexplained for a long time. With this in mind, the author conducted theoretical research aimed at eliminating existing complications of the αΩ dynamo model. To calculate the key factors of the dynamo model, nonlinear turbulent effects of macroscopic MHD and data from modern helioseismological experiments on the internal rotation of the Sun were used. The reformed model covers the updated α effect (change of sign of the helicity parameter in the deep layers of the SCZ, the magnetic alpha quenching, the influence of rotation on the helicity of turbulent motions), processes of turbulent reconstruction of global magnetism (turbulent macroscopic diamagnetism, "negative magnetic buoyancy"), the impact of turbulence on the electrodynamic parameters of the plasma (macroscopic electrical conductivity and magnetic permeability), physical processes in the layers of overshoot convection and the radiative tachocline. This allowed to expand the notitia of observed magnetic cyclic phenomena that can be described within the framework of an improved αΩ dynamo model.

SPECTRAL ANALYSIS AND FORWARD MODELING OF TERRESTRIAL EXOPLANETS AND MINI-NEPTUNES USING THE TAUREX 3 FRAMEWORK

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We report the results of atmospheric characterization and forward modeling for a diverse sample of exoplanets, specifically focusing on the mini-Neptunes K2-18b, TOI-270d, and LTT 3780c, as well as the Earth-sized terrestrial exoplanet LHS 475b. For the sub-Neptune regime, our theoretical models are designed to evaluate the spectral signatures of key biosignature gases (including CH4, CO2, O3, and N2O) and to simulate the effects of high-altitude opaque clouds at the 10 mbar pressure level. For LHS 475b, the study focuses on evaluating the potential presence of a secondary atmosphere and modeling the spectral impact of various abundances of major volatile constituents.

The investigation utilizes high-precision simulated data corresponding to the broad-band infrared coverage of JWST's NIRISS (0.8-2.8 μm) and NIRSpec (2.7-5.2 μm) instruments. Forward modeling based on radiative transfer equations is implemented within the TauREx 3 framework. To maintain consistency with observational resolving power, all theoretical transmission spectra were convolved with a Gaussian filter(σ=30).

By applying comparative spectral analysis, we quantify the impact of photochemical hazes and cloud deck muting on the transmission spectra. Our preliminary findings demonstrate how specific Temperature-Pressure (T-P) profiles dictate the detectability of molecular features, and highlight the threshold at which high-altitude clouds obscure the atmospheric signatures of terrestrial and sub-Neptune worlds. This approach emphasizes the critical role of combining multi-instrument observations with rigorous forward modeling.

MONITORING OF THE GEOMAGNETIC FIELD IN UKRAINE

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Geomagnetic field monitoring in Ukraine is carried out in 3 geomagnetic observatories (GOs), which are part of the INTERMAGNET network: "Kyiv" (KIV), "Lviv" (LVV) and "Odesa" (ODE), at 3 geophysical stations (GSs) ("Nyzhne Selishche (NS)", "Trosnyk" (Tr). "Brid" (Br)) at the Carpathian geodynamic polygon, as well as at 55 Repeat Stations (RSs). In GOs, continuous (with an interval of 1 min or 1 sec) registration of variations in the geomagnetic field components is performed. At RS, measurements of all components of the geomagnetic field vector are performed during the next observation cycle. At the GS, measurements of the ***B*** module are performed around the clock with an interval of 1 measurement after 10 min. Also, registration of geomagnetic field variations is performed at the "Mayaki" point, at the location of the Uran-4 radio telescope.

Geomagnetic field monitoring in observatories has been carried out almost continuously for the past 65 years, and several cycles of observations have been carried out at the RSs (2005, 2010 and partially in 2015). The Kyiv Observatory was destroyed in 2022 and observations were resumed in 2025.

The following set of instruments is required for observations in the GOs and at the RSs: *magnetovariation station* (for measuring variations of the northern *Bx*, eastern *By* and vertical *Bz* components of the geomagnetic field); *proton magnetometer* (for measuring the induction modulus of the geomagnetic field); *DI-magnetometer* (non-magnetic theodolite with a ferroprobe) for measuring angular (declination *D* and inclination *I*) elements of the geomagnetic field vector) and determining the absolute values of *Bx*, *By*. *Bz* and their reduction to the epoch observations. Preliminary and final processing of geomagnetic observations at magnetic observatories and RSs is performed using the INTERMAGNET method.

The method involves calculating 1-second or 1-minute absolute values of the force (*Bx, By, Bz*) and angular (*D, I*) components of the geomagnetic field vector using continuous variational and periodic module measurements. Subsequently, the absolute values of the geomagnetic field components are calculated for different time intervals (1 hour, day, month, year, etc.).

Based on the results of monitoring observations and different-time and different-scale geomagnetic surveys, a model of the geomagnetic field of the territory of Ukraine was developed for the time interval 1900-2025, its spatio-temporal changes were estimated, and maps of the module and anomalies of the induction module of the geomagnetic field and its components, in particular magnetic declination, which are widely used for geology, orientation, navigation, humanitarian demining, etc. Currently, in close cooperation with the Radio Astronomy Institute of the National Academy of Sciences of Ukraine, the Institute of Geophysics of the Polish Academy of Sciences and Ventspils University of Applied Sciences, a comprehensive interpretation of geomagnetic and radio astronomical observations is being carried out regarding the study of the solar-terrestrial connection, magnetospheric-ionospheric phenomena and certain aspects of space weather in the vicinity of the meridian of the "Struve Geodetic Arc".

THE RELATIONSHIP BETWEEN THE EARTH'S MAGNETIC FIELD, SEISMICITY, AND TEMPERATURE WITH ITS ROTATIONAL MODE

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The report presents the results of a study on the changes from 1900 to 2025 for the planet Earth on its surface in the length of the day, the main magnetic field, seismicity and temperature. Over the past 125 years, there has been a significant decrease in the induction modulus of the geomagnetic field, an increase in seismicity and the temperature of the Earth. The following regional extremes of geophysical fields and phenomena were identified:

a) length of day: 1905.0±2.5 (3.6 ms/year; 1936±2.5 (0.3 ms/year); 1972.5±2.5 (3 ms/year). Then there is a decrease in the length of day, against the background of which relative maxima and minima stand out: 1986±2.5 (1.2 ms/year); 1993±2.5 (2.1 ms/year); 2004±2.5 (0.2 ms/year); 2014±2.5 (1.3 ms/year); 2022±2.5 (-0.3 ms/year);

b) main magnetic field BIGRF: 1917.5±2.5 (-90 nT/year); 1945.5±2.5 (-25 nT/year); 1978.5±2.5 (-70 nT/year); 2022.5±2.5 (-10 nT/year);

c) seismic activity: 1910±2.5 (16); 1930±2.5; (58); 1948±2.5 (40); 1954±2.5 (70); 1980±2.5 (38); 2010±2.5 (100); 2020±2.5 (45);

d) temperature: 1910±2.5 (-0.55°C); 1944±2.5 (0.15°C); 1975±2.5 (-0.15°C); 2010±2.5 (0.46), starting from 2015 the rate of temperature increase increases in relation to background changes.

A comparison of regional extremes of changes in the length of the day, the main magnetic field; seismicity and temperature has been made. It has been shown that fundamental changes in the geomagnetic field, seismicity and temperature on the Earth's surface are caused, first of all, by its rotational mode. The dynamics of these Earth parameters have also been compared with the Large-scale magnetic field of the Sun and its activity.

FEATURES OF THE LOWER SOLAR ATMOSPHERE DYNAMICS DURING A POWERFUL X2.3-CLASS FLARE

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We present the results of a spectral study of the lower solar atmosphere dynamics under the influence of a powerful X-ray flare X2.3-class, optical magnitude 3B. The flare occurred on May 9, 2024, in superactive region (AR) NOAA 13664. AR produced very strong flares, accompanied by powerful coronal mass ejections (CMEs), which on May 10-12 triggered on Earth the extreme geomagnetic storm the highest category G5. The flare we're investigating was one of these flares. It occurred at 08:45 UT on May 9 and lasted 46 minutes. It's maximum was at 08:13 UT. The flare produced a very powerful CME with a velocity of 1280 km/s at 09:24 UT.

The spectrograms of the flare, centered on the Hα line, were recorded with the Ernest Gurtovenka solar horizontal telescope of the Main Astronomical Observatory in Kyiv. During 22 min of observations (09:14:44–09:36:51 UT), three time series of spectra in different sites of the flare were recorded, which included various flare kernels. We studied the flare site which was observed from 9:33:28 to 9:37:03 UT during main phase flare. The spectrograph slit crossed two flare kernels (f1 and f2), located at a distance of 23.4 Mm from each other, and three pores. Kernel f1 was brighter, kernel f2 was partially located above the pore. The spectral region of λλ 655.3 – 657.2 nm was used, which included the chromospheric Hα line and the Fraunhofer lines FeI, SiI, TiI, which are formed in different layers of the photosphere. The Hα line emission profiles for kernels f1 and f2 were wide, and had blue asymmetry. For kernel f2 they also had absorption in the line core and were two-peaked with a stronger blue peak, their shape corresponded to the shape of theoretical profiles obtained taking into account the influence of nonthermal electron beams on the chromosphere. The Hα line light curves for the flare kernels f1 and f2 consisted of peaks series at intervals of about 34 s, indicating that at this time a pulsed release of flare energy occurred as a result of successive intermittent magnetic reconnections. Line-of-sight velocities (Vlos), determined relative to the undisturbed atmosphere, showed that chromospheric matter in the region occupied by flare

kernels was rising (at Vlos of up to -1.3 km/s), with the highest Vlos of up to -2.3 km/s in the region between them. In neighboring regions, a descent of chromospheric matter was observed at a velocity of up to 2.5 km/s. The velocity changes over time were oscillatory.

Changes in different photospheric layers were of different nature. The intensity of the Fraunhofer lines FeI and SiI increased compared to the unperturbed photosphere, while the intensity of the TiI line decreased. The velocity changes in the photosphere were oscillatory. In flare kernel f1 photospheric matter ascended, while in flare kernel f2 both upflows and downflows were observed. In the studied site AR, photospheric material rose on one side of the region occupied by the flare kernels and descended on the its other side, with velocities varying from -1.2 to 0.6 km/s at different levels of the photosphere.

THE ROLE OF N-S ASYMMETRY AND ACTIVITY COMPLEXES IN THE MANIFESTATION OF FLARE ACTIVITY OF THE 25TH CYCLE

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We investigate the main characteristics of the dynamics of Solar Cycle 25 and the role of complexes of activity (CAs) in its evolution. It is suggested that solar activity develops independently in the northern and southern hemispheres, where latitudinal zones of CA formation are generated.

The most intense manifestations of flare activity occur during the formation of longitudinal CAs that connect activity centers in the northern and southern hemispheres. The principal periods of activity-center formation during different phases of the solar cycle are identified. The spatial characteristics of the CAs are derived using daily mean values of the Wolf sunspot number, sunspot-group areas, and the flare index.

The evolution of flare activity associated with two major activity complexes is analyzed in detail: (1) the giant activity complex in the northern hemisphere during 1–7 February 2025, and (2) the activity complex linking sunspot groups in the northern and southern hemispheres during 27 June–6 July 2026. The analysis utilizes solar radio maps at a wavelength of 8 mm obtained from the Metsähovi Radio Observatory Solar Gallery.

Finally, the prospects for using the VIRAC RT-32 radio telescope, in conjunction with the Metsähovi Radio Observatory RT-14 radio telescope, for coordinated solar observations in the centimetre and millimetre wavelength ranges are discussed.

CATALOGUE OF SOLAR RADIO BURSTS DETECTED BY THE LOFAR LV614 STATION AT THE IRBENE OBSERVATORY DURING SOLAR CYCLE 25

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A cataloguea of solar radio bursts detected with the LV614 LOFAR station at the Irbene Observatory, Latvia, in the stand-alone mode from June 2022 to August 2025 in the 29–60 MHz frequency range is presented. Observations were conducted with the weekly cadence, one-second time resolution, and 0.195 MHz spectral resolution.

The cumulative duration of the observation was 1125.2 h. For all analysed observations, bandpass calibration was applied using Cassiopeia A as a reference source. In total, the catalogue includes 335 solar radio bursts. Radio bursts of all five main types, I–V, were detected. Specifically, the catalogue contains parameters of 23, 8, 293, 6, and 5 bursts of Type I, II, III, IV, and V, respectively. The detected burst peak flux ranges from 0.3 SFU to 234 SFU. The catalogue provides information about the peak flux and frequency, and the estimated height of the source above the solar surface. For Type II and III bursts, we also give the estimations of the instantaneous frequency drifts, with mean values 0.043 MHz s−1 and 4.383 MHz s−1, respectively. The numbers of Type I and III events are found to decrease with the peak flux, with the power law indices about −0.9 and −1.25, respectively.

DIAGNOSTICS OF SOLAR ECLIPSES AS MANIFESTATIONS OF SPACE-WEATHER EFFECTS BASED ON IONOSPHERIC SCINTILLATIONS OF COSMIC RADIO SOURCES AND GEOMAGNETIC-FIELD VARIATIONS RECORDED BY THE INTERNATIONAL MAGNETOMETER NETWORK

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Solar eclipses constitute unique natural experiments that enable investigation of the dynamics of solar–terrestrial coupling under conditions of abrupt changes in illumination and ionospheric structure. When the Moon obscures the solar disk, a rapid decline in photoionization

occurs in the upper atmosphere, leading to a reconfiguration of electron density, modifications of ionospheric layers, and the formation of local gradients. These processes initiate a cascade of effects that can be detected by highly sensitive ground-based instruments. Ionospheric scintillations in the decameter radio band (10–30 MHz) represent one of the most sensitive natural detectors of atmospheric gravity waves (AGW) and traveling ionospheric disturbances (TID) generated during solar eclipses. Geomagnetic pulsations arising as the ionospheric response to altered conditions in the solar wind and magnetosphere are also of considerable interest. During eclipse intervals, changes are observed in the amplitude and spectral composition of ULF oscillations, including the predominance of irregular Pi-type pulsations. Their analysis makes it possible to assess the degree of coupling between ionospheric currents and magnetospheric resonances. Equally important are decameter ionospheric scintillations, manifested as intensity fluctuations of cosmic radio sources in the 10–30 MHz band. During eclipses, plasma structures modified by acoustic–gravity waves (TIDs) lead to variations in radio-wave refraction and scattering, making such observations a valuable diagnostic tool for studying ionospheric turbulence across multiple spatial scales. The study demonstrates that, during the passage of the lunar umbra and penumbra, Pi-type geomagnetic pulsations in the Pc3–Pc5 period range exhibit an irregular, broadband, impulsive character and intensify at the edge of the penumbra (5–20% solar-disk coverage), but weaken in regions where coverage reaches 80% or more. The fine structure of geomagnetic pulsations and ionospheric scintillations of cosmic sources during the eclipse is also examined, using data from the Ukrainian national geomagnetic network, the international INTERMAGNET network, and the radio telescopes URAN-4 (Ukraine), LOFAR LV614 (Latvia), LOFAR (Germany), and KAIRA (Finland).

OCTOBER 1989 GEOMAGNETIC SUPERSTORM: REVITALIZING ARCHIVAL URAN-4 (IRA NASU) ANALOG MONITORING

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During the extremely active peak of solar activity of the 22nd cycle, a superflare of class X13/4B occurred with subsequent coronal mass ejection, which provoked an extreme geomagnetic storm with maxima between October 20-22, 1989. This event became one of the largest during the 22nd cycle and caused the second largest magnetic storm in that cataclysmic year.

After commissioning, a program was implemented to monitor powerful space radio sources using the RT URAN-4 at frequencies of 20 and 25 MHz in two polarizations. The list of objects included the radio galaxies Virgo A (3C 274) and Cygnus A (3C 405), as well as the remnants of the supernova Taurus A (3C 144) and Cassiopeia A (3C 461). In addition to the effectiveness of such data in studying the state of the ionosphere, it later turned out that they are of particular interest for studying historical geomagnetic storms and space weather.

Prior to 1993, signals were recorded on the radio telescope in analog mode via paper chart recorders. This precluded the possibility of studying the obtained observations using modern digital time-frequency methods. To address this issue, a specialized Python library was developed to convert archival recordings into digital format.

This paper presents digitized monitoring data from October 16–23 at 20 and 25 MHz (both polarizations) and provides an analysis of the signal's spectral composition and the ionospheric scintillations parameters, using wavelet and superlet analysis methods to characterize main scintillation periods and their evolution.

COMPARATIVE ANALYSIS OF PLASMA FLUCTUATIONS IN ACTIVE AND QUIET REGIONS OF THE LOWER SOLAR ATMOSPHERE

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Solar active regions are the source of many energetic and geo-effective events such as solar flares and coronal mass ejections. Understanding how these complex source regions evolve and produce these events is very important not only to solar physics, but also to the demands of space weather forecasting. In this report we present a comparative analysis of plasma fluctuations in active (plage) and quiet regions of the lower solar atmosphere. Our analysis was based on expressions for spatial spectrum and rms level of fluctuations generated via turbulent mixing in partially ionised plasma. The consideration was made for the lower solar atmosphere under the rise of magnetic field strength from 100 to 1000 G in plages and from 0.5 to 5 G in quiet regions. It was shown that the rms amplitude of fluctuations (with length-scales smaller than 100 km) has to increase with strength of magnetic field. The spatial spectrum of plasma fluctuations (if approximated by a power law) has to change too with magnetic field, its power index has to increase. Our comparative analysis has shown that plasma fluctuations in active (plage) and quiet regions of the lower solar atmosphere have evident difference. In particular the difference has to result in distribution of magnetic field in the solar atmosphere.

ASTRONOMICAL EDUCATION AND OUTREACH

PROFESSIONAL-AMATEUR (PRO-AM) ASTRONOMY. STATISTICALLY OPTIMAL MODELING OF ASTRONOMICAL SIGNALS WITH GENERALLY UNEVENLY SPACED ARGUMENTS

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Professional–Amateur (Pro–Am) collaboration started long time ago, when there were no professionals getting salary for astronomers. With an increasing level of civilization, the interest in astronomy was growing, and there is a separation into people working in this profession, and otherm who work anywhere, and make activities, as a hobby, in the free time.

Definitely, there is a wide distribution of the level of activity from "watch the sky", look with a telescope, to buy a telescope and to make astrophotos. However, many people, from single astrophotos of dozens beautiful celestial bodies, want to make contribution to science. In astronomy, it is a real possibility: to monitor possibe changes in the sky - mainly variable stars (eruptive, pulsating, eclipsing), sometimes, asteroids, sunspots, asteroid impacts to the Moon or Jupiter, meteors etc. The value of the amateur observations is in contributing to the databases. Professional astronomers can't observe continuously every star. But thousands of amateur astronomers may observe thousands of stars per night, and report immediatedly on the beginning of the outbursts of Supernova, nova, dwarf nova etc. Or observe quiet pulsating or eclipsing targets to determine e.g. times of maxima/minima (ToM, in the terminology of the AAVSO - American Association of variable stars observers).

AAVSO (aavso.org, USA) was founded in 1911, and currently is a global leader in the database of the single observations. At the time of writing this abstract, there were 84730514 original observations of 2000+ variable stars/ Currently, members from 100+ countries (and national association) contribute to this globalistic structure.

However, the first (1890) was BAA VSS (British Astronomical Association – Variable Star Section) in the United Kingdom 1890 (same year BAA was founded). Then similar associations were founded in other developed countries:

ČAS(Česká astronomická společnost, 1917, from 1993, split into Czech and Slovak branches)

PTMA (Polskie Towarzystwo Miłośników Astronomii, Poland, 1919)

AFOEV (Association Française des Observateurs d'Étoiles Variables, France, 1921),

BAV (Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne, Germany, 1950)

UAI VSS (Unione Astrofili Italiani – Sezione Stelle Variabili, Italy, 1967)

VSOLJ (Variable Star Observers League of Japan, 1970), etc. (established as a national league of amateur observers) Coordinates Japanese observers; publishes VSOLJ Circulars; collaborates with AAVSO and others.

These associations form the backbone of Pro–Am astronomy, enabling amateurs worldwide to contribute scientifically valid data. Their archives are critical for:

Long-term monitoring of variable stars.

Period analysis and statistical modeling.

Supporting professional research with continuous datasets.

Sometimes making scientific alerts for the "target of opportunity" observations at the orbital and ground-based observatories.

Currently, all national databases are inclused in the AAVSO one, which is the world-wide database.

AAVSO issues awards to most active observers worldwide. From Ukraine, such awards have Oleksandr Baransky (2003) and Maksym Pyatnytskyy (2020) - amateurs with PhDs in Biology and Physics (not astronomy, so "amateurs").

In the recent decades, there is a synonym to "Pro-Am". "Citizen astronomy" refers to the active participation of non-professional observers in scientific research, often in collaboration with professional astronomers. It has become one of the most successful branches of "citizen science", especially in the study of variable stars, exoplanets, comets, and transient phenomena.

For such "Big data", the mathods for mathematical modeling are supposed to be adequate and have a statistically optimal number of parameters. However, there may be algorithms. which are oversimplified amd may produce bias results, e.g. using a simply sine (instead of e.g. a trigonometrical polynomial or a generalized spline, like NAV) to approximate an eclipsing light curves with narrow minima, or pulsating variables with a large asymmetry. or. for determination of extrema, a classical oversimple approximation by a parabola, gaussian, or even a modified gaussian.

Traditional approaches to time-series analysis often rely on oversimplified mathematical models that neglect the orthogonalization of basis functions. Such simplifications can introduce statistical biases, distort spectral power distributions, and lead to erroneous conclusions about periodicities or physical parameters of variable stars. The modification of the Lomb method in 1975 provided a breakthrough by enabling spectral analysis of unevenly spaced data, but subsequent research has demonstrated that further refinements are necessary to ensure statistical optimality. In particular, the orthogonality of basis functions must be preserved to avoid spurious correlations and inflated significance levels.

This talk presents a framework for statistically optimal phenomenological modeling of astronomical signals with unevenly spaced arguments, integrating both professional and amateur datasets. The methodology emphasizes:

– rigorous orthogonalization of basis functions in finite Fourier (trigonometric polynomial with) and polynomial expansions, as well as generalized splines:

– statistically correct estimation of uncertainties and confidence intervals,

– avoidance of pre-whitening and detrending procedures that compromise statistical validity,

– application of a "net of algorithms" tailored to diverse classes of variable stars, including cataclysmic, symbiotic, eruptive, long-period, and eclipsing systems.

The list of our papers on time series analysis is on uavso.org.ua/mavka . There are also links to the free programs MCV (Written with A.V.Baklanov) for periodogram analysis of multi-harmonic signals with trends, approximation of multi-periodic multi-harmonic signals with trend and dozens other options. MAVKA allows to determine times of extrema with the best statistial accuracy. It implements 22 functions of 11 types.

INTRODUCTORY STATISTICS FOR ASTRONOMERS AND NOT ONLY/ A TEXTBOOK

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"Every science has as much science, as it has Mathematics in it" (Emmanuel Kant). Statistics serves as the foundational language of empirical investigation across an extraordinary breadth of disciplines. In astronomy, it allows researchers to distinguish subtle celestial signals from cosmic noise. In the natural sciences, statistical methods provide the rigorous framework required to validate experimental results and model biological and physical phenomena. Within technology (engineering), data-driven insights power machine learning algorithms, optimize complex systems, and ensure the reliability of digital infrastructures.

The utility of statistics extends deeply into the human sciences: it facilitates the analysis of market trends and macroeconomic stability in economics, informs strategic planning and service optimization in tourism, reveals structural patterns in social science research, and aids in the quantitative analysis of linguistic and stylistic evolution in philology. Regardless of the field, the ability to collect, interpret, and make inferences from data is an indispensable tool for turning raw information into actionable knowledge.

We present a new textbook provides a comprehensive introduction to these essential methodologies, bridging the gap between theoretical probability and practical data analysis. It guides students through the fundamental principles of statistical modeling, the systematic study of variability, the analysis of relationships between phenomena, and the interpretation of dynamic change. By mastering these techniques, students gain the analytical clarity necessary to navigate complex datasets and contribute evidence-based solutions to their respective fields of study.

The main topics are: Integral and Differential Distribution Functions of Random Variables. Numerical characteristics. Uniform, normal, exponential, and Poisson distribution laws; their numerical characteristics. Statistical estimation of distribution parameters. Verification of statistical hypotheses. Absolute and Relative Indicators and Values: Types, Use, and Significance. Methods of calculation and interrelationships. Essence and significance of average indicators. Forms of average values. Arithmetic mean: calculation methods and properties. Other types of averages and their calculation order. Construction of Distribution Series. Indicators of the center of distribution. Indicators of variation (fluctuation) of a feature. Addition of variances of the studied feature. Variations of an alternative feature. Concepts of distribution forms. Distribution curves. Essence of sampling observation. Simple random sampling. Stratified (typical or raioned) sampling. Cluster sampling. Mechanical sampling. Combined sampling. Multi-stage sampling. Causal Relationships of Socio-Economic Phenomena. Main stages of statistical study of interrelation and interdependence. Criteria for determining the connection of phenomena, types of connections: direct and inverse, linear and curvilinear, single-factor and multi-factor, functional and correlation. Tasks and prerequisites for applying correlation-regression analysis. Basic conditions for use and procedure. Assessment of the significance of the relationship using coefficients.

Concepts and Classification of Dynamic Series (Time Series). Comparability of levels and closing of dynamic series. Indicators of change in dynamic series levels: absolute growth, growth coefficient or growth rate, absolute and relative acceleration. Methods for calculating the average level of interval and moment dynamic series. Methods for analyzing trends in dynamic series: aggregation of intervals, moving averages, and other methods of smoothing levels. Concepts and Classification of Indices. Individual and general indices. Aggregate index as a complex relative indicator; methodology of construction. Basic forms of calculating consolidated or general indices. Selection of the comparison base and types of indices. Index system. Significance of indices for the recalculation of macroeconomic indicators in tourism etc. Concepts of a Statistical Graph and Its Elements. Classification of graphs. Types of graphs. Varieties of diagrams.

INNOVATIVE TEACHING TOOLS FOR ASTRONOMY IN SCHOOLS AND HIGHER EDUCATION INSTITUTIONS

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An innovative set of materials has been developed as a methodological toolkit for organizing independent work in astronomy in accordance with the current standard-level curriculum under the supervision of Ya. S. Yatskiv. The content encompasses all the fundamental sections of the course, ranging from the basics of the celestial sphere and

the historical progression of astronomy to the intricacies of stellar physics, cosmology, and the pursuit of extraterrestrial life.

The structure of the independent assignments is integrative, combining tasks of different types. These include conceptual work with terminology, construction of hierarchical schemes, and graphical activities (including the modelling of light paths in telescopes and elements of the celestial sphere). In addition, there is visual identification of both astronomical objects and prominent scientists. This approach has been demonstrated to facilitate not only subject-specific knowledge acquisition but also the development of visual literacy and spatial thinking.

The methodological toolkit incorporates contemporary educational technologies, including interactive assessment tools (e.g. LearningApps) and project-based learning elements (e.g. the creation of 3D books, models, thematic presentations, and reports). The system of tasks is differentiated, ranging from reproductive to productive-creative levels, which enables the implementation of a competency-based approach and fosters the development of linguistic, mathematical, and digital competencies.

The effectiveness of the proposed toolkit is supported by the results of long-term implementation: its integration into the practice of a secondary education institution (Kryvyi Rih Gymnasium, approximately 50 students) and its use in the training of future physics and astronomy teachers at a higher education university (over 100 students during 2021–2026). The findings indicate heightened motivation to study astronomy and enhanced learning outcomes. The materials are suitable for use in both secondary and higher education contexts.

OPEN-SOURCE SOFTWARE TOOLS FOR PERIODOGRAM ANALYSIS AND PHOTOMETRIC DATA PROCESSING

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We present a set of new open-source software tools, LightCurveViewer (LCV) and VS-fit, developed primarily for the analysis of light-curve periodograms. These programs were inspired by the well-known MCV software package created by Professor Ivan L. Andronov. They preserve the principal methods of periodogram analysis and light-curve approximation available in MCV while providing a more user-friendly interface and compatibility with modern hardware and software platforms, including multi-core processors and contemporary operating systems.

In addition, we present several other tools, including a number of compact Python scripts, that may be useful for photometric data reduction and the analysis of archival datasets, particularly those obtained by the TESS mission.

The mentioned programs are available at the following links: https://github.com/mpyat2/LightCurveViewer (LCV) and https://github.com/mpyat2/VS-fit (VS-fit).

POPULARIZATION OF ASTRONOMY AND PLANETARIUM IN UKRAINE

THE UNIVERSALISM OF KEPLER'S SCIENTIFIC LEGACY: LAWS OF MOTION, OPTICS, AND TIDAL THEORY

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This presentation provides a comprehensive review of the scientific legacy of Johannes Kepler (1571–1630), one of the pivotal figures of the 17th-century Scientific Revolution. The study analyzes three primary dimensions of his work that laid the groundwork for classical physics and astronomy.

The first section highlights the derivation of Kepler's three laws of planetary kinematics based on Tycho Brahe's observational archives, a breakthrough that dismantled the 2000-year-old dogma of circular orbits and solidified the heliocentric system. The second part focuses on his revolution in geometric and anatomical optics, including the formulation of the inverse-square law for illuminance, the explanation of the retinal mechanism of human vision, and the invention of a groundbreaking optical design for the refracting telescope utilizing two convex lenses. The third dimension explores Kepler's contribution to geophysics, specifically his debate with Galileo Galilei and his pioneering physical justification of tides as a phenomenon driven by the gravitational attraction of the Moon and the Sun.