Fourth UK-Ukraine-Spain Meeting on Solar Physics and Space Science

PROGRAMME, ABSTRACTS, INFORMATION

28 August –1 September, 2017
Kyiv, Ukraine

Organised by

Solar and Terrestrial Atmospheres Research Laboratory,
The University of Sheffield, UK

Space Plasma Department, Institute of Space Research, Ukraine

Taras Shevtchenko National University of Kyiv, Ukraine

The University of Northumbria at Newcastle, UK

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Content

Note that the abstracts are given in the order the talks are presented at the meeting with the name of the session and the day provided in the page header.

Programme overview

Monday 28 August 2017	08:30 – 09:30	*Registration*
	09:30 – 11:00	Dynamic processes in the Earth ionosphere and magnetosphere
	11:00 – 11:30	*Break, discussion and poster session*
	11:30 – 12:25	Dynamic processes in the Earth ionosphere and magnetosphere
	12:25 – 14:00	*Lunch*
	14:00 – 15:30	Dynamic processes in the Earth ionosphere and magnetosphere
	15:30 – 16:00	*Break, discussion and poster session*
	16:00 – 17:05	Dynamic processes in the Earth ionosphere and magnetosphere
	17:05 – 17:45	Discussion
	18:30	*Icebreaker (Opanas Restaurant)*

Tuesday 29 August 2017	09:00 – 11:00	MHD waves (observations, theory, numerics)
	11:00 – 11:30	*Break, discussion and poster session*
	11:30 – 12:30	MHD waves (observations, theory, numerics)
	12:30 – 14:00	*Lunch*
	14:00 – 15:30	MHD waves (observations, theory, numerics)
	15:30 – 16:00	*Break, discussion and poster session*
	16:00 – 17:20	MHD waves (observations, theory, numerics)
	17:20 – 18:00	Discussion

Wednesday 30 August 2017	09:00 – 11:00	General solar activity in the Sun and heliosphere
	11:00 – 11:30	*Break, discussion and poster session*
	11:30 – 12:30	General solar activity in the Sun and heliosphere
	12:30 – 14:00	*Lunch*
	14:00	*Excursion*

Thursday 31 August 2017	09:00 – 11:00	MHD waves (observations, theory, numerics)
	11:00 – 11:30	*Break, discussion and poster session*
	11:30 – 12:30	MHD waves (observations, theory, numerics)
	12:30 – 14:00	*Lunch*
	14:00 – 15:30	MHD waves (observations, theory, numerics)
	15:30 – 16:00	*Break, discussion and poster session*
	16:00 – 17:40	MHD waves (observations, theory, numerics)
	17:40 – 18:00	Discussion
	19:00	*Dinner, Opanas Restaurant*

Friday 1 September 2017	09:00 – 11:00	Multi-scale plasma dynamic processes in the Sun-Earth system
	11:00 – 11:30	*Break, discussion and poster session*
	11:30 – 12:45	Multi-scale plasma dynamic processes in the Sun-Earth system
	12:45 – 12:55	Final words. Conference closed

IT – Invited Talk – 30 min +5 min questions
ICT – Invited Contributed Talk – 25 min + 5 min questions
CT – Contributed Talk – 20 min + 5 min questions
P – Poster presentation – 5 min

08:00 – 09:30 Registration

Dynamic processes in the Earth ionosphere and magnetosphere

Oral Session (Morning). Convener O. Cheremnykh

09:30 – 10:05 Y. Rapoport: Models of the Atmospheric Gravity Wave-Electromagnetics Coupling and Planetary Electromagnetic Waves in the Ionosphere: progress in the development (IT)
10:05 – 10:30 K. Kurt: The polarization of a characteristic electromagnetic wave in ionospheric plasma (CT)
10:30 – 11:00 A. Koval: Ionospheric Focusing Effect in Meter-Decameter (ICT)
11:00 – 11:30 ***Break, discussion and poster session***
11:30 – 11:55 I. Kundelko: Analysis of the geomagnetic pulsations during a substorm (CT)
11:55 – 12:20 A. Yesil: The loss-tangent tensor for ionosphere plasma in northern hemisphere (CT)
12:20 – 12:25 Y. Kyzyurov: On the determination of turbulent energy dissipation rate from sporadic-E parameters in the lower ionosphere (P)
12:25 – 14:00 ***Lunch***

Oral Session (Afternoon). Convener Y. Voitenko

14:00 –14:30 S. Cheremnykh: Oscillations of ULF waves in the Earth's magnetosphere (ICT)
14:30 – 15:00 D. Graham: Role of waves in magnetic reconnection at Earth's magnetopause: MMS observations (ICT)
15:00 – 15:25 A.Prokhorenkov: Cascade processes in the Earth magnetosphere (CT)
15:25 – 15:30 B.Petrenko: The turbulence processes in the Earth magnetotail (P)
15:30 – 16:00 ***Break, discussion and poster session***
16:00 – 16:30 L. Kozak: Analysis of the turbulent processes in the geospace (ICT)
16:30 – 16:55 S. Shestov: ASPIICS spaceborne coronagraph (CT)
16:55 – 17:00 S. Sharma: Study of nonlinear evolution of dispersive Alfven waves and driven plasma turbulence in solar wind (P)
17:00 – 17:05 E. Popova: On a role of quadruple component of magnetic field in defining solar activity in grand cycles (P)
17:05 – 17:45 ***Discussion***
18:30 ***Ice-breaker, Opanas Restaurant***

MHD waves – coupling between lower solar atmosphere and solar corona (observations, theory, numerics)

Oral Session (Morning). Convener V. Fedun

09:00 – 09:35 I. Ballai: Nonlinear plasma processes in partially ionized plasmas (IT)

09:35 – 10:10 S. Shelyag: Do photospheric non-magnetic bright points exist? (IT)

10:10 – 10:35 M. Barbulescu: Magnetoacoustic Waves and the Kelvin-Helmholtz Instability in a Steady Asymmetric Slab (CT)

10:35 – 11:00 A. Kryshtal: Kink mode in magnetic tube with discontinuous magnetic field (CT)

11:00 – 11:30 ***Break, discussion and Poster Session***

11:30 – 12:05 N. Shchukina: Progress Magnetic fields of the quiet Sun. What do we know about them? (IT)

12:05 – 12:30 D. Przybylski: Dissipation of Alfven waves through ion-neutral interactions (CT)

12:30-14:00 ***Lunch***

Oral Session (Afternoon). Convener R. Kostik

14:00 – 14:35 V. Yurchyshyn: Sunspot Studies with the New Solar Telescope at the Big Bear Solar Observatory (IT)

14:35 – 15:00 B. Snow: Observational signatures of a kink-unstable coronal flux rope using Hinode/EIS (CT)

15:00 – 15:30 V. Olshevsky: Towards Lagrangian modeling of solar wind propagation in the heliosphere (ICT)

15:30 – 16:00 ***Break, discussion and Poster Session***

16:00 – 16:25 Z. Vashalomidze: Spectral Inversion of the Halpha and Ca II 8542 A Lines Observed by SST/CRISP in Chromospheric Jets (CT)

16:25 – 16:50 T. Kaladze: Fast Magnetohydrodynamic Cnoidal Waves and Solitons in Electron-Positron Plasma (CT)

16:50 – 17:15 A. Monga: Giant prominence eruption associated with fast CME (CT)

17:15 – 17:45 E. Scullion: A beginners guide to the DKIST critical science plan (ICT)

17:45 – 17:50 E. Goldstraw: 5 MHD Methods for Coronal Loops (P)

17:50 – 18:20 ***Discussion***

General solar activity in the Sun and heliosphere

Oral Session (Morning). Convener S. Shelyag

09:00 – 09:25 V. Zharkova: Reinforcing the double dynamo model with solar-terrestrial activity in the past three millennia (CT)
09:25 – 09:55 R. Kostik: Long-term variations of the quiet Sun with 11-year cycle of solar activity (ICT)
09:55 – 10:20 M. Pishkalo: Sun's magnetic field reversal in cycle 24 (CT)
10:20 – 10:55 M. Pishkalo: Preliminary prediction of solar cycle 25 (CT)
10:55 – 11:00 V. Krivodubskij :Double maximum of solar cycle (P)
11:00 – 11:30 ***Break, discussion and poster session***
11:30 – 12:05 Y. Tsap: On the propagation of transverse waves along thin gravity stratified magnetic flux tubes in the lower solar atmosphere (IT)
12:05 – 12:30 G. Gogoberidze: Very high frequency temperature spectrum in the solar wind (CT)
12:30 – 14:00 ***Lunch***

14:00 ***Excursion***

MHD waves – coupling between lower solar atmosphere and solar corona (observations, theory, numerics)

Oral Session (Morning). Convener V. Zharkova

09:00 – 09:35 S. Zharkov: So, what is a sunquake? (IT)
09:35 – 10:05 M. Druett: Beam electrons as a source of Balmer and Paschen emission in solar flares (ICT)
10:05 – 10:30 V. Fedun: Jet formation in solar atmosphere: 2-3D numerical study (CT)
10:30 – 11:00 S. Shestov: Nonlinear evolution of short-wavelength torsional Alfven waves (ICT)
11:00 – 11:30 ***Break, discussion and Poster Session***
11:30 – 12:05 B. Li: Collective MHD waves in solar coronal structures with continuous transverse structuring: theories and seismological applications (IT)
12:05 – 12:30 O. Cheremnykh: MHD wave modes of twisted magnetic flux tube: long wavelength approximation (CT)
12:30 – 14:00 ***Lunch***

Oral Session (Afternoon). Convener A. Kryshtal

14:00 – 14:35 Y. Voitenko: MHD-kinetic transformation of Alfvénic turbulence and future space missions (IT)
14:35 – 15:00 O. Lyubchyk: Solar plasma radio emission in the presence of imbalanced turbulence of kinetic-scale Alfven waves (CT)
15:00 – 15:30 G. Vigeesh: Energy transport by internal gravity waves in magnetized solar atmosphere (ICT)
15:30 – 16:00 ***Break, discussion and poster session***
16:00 – 16:35 L. Pustilnik: Flare Energy Release: Internal Conflict, Contradiction with high resolution observations, possible solutions (IT)
16:35 – 17:00 Y. Kolesnyk: An exact solution of energy particles modulation problem in a stationary composite heliosphere model (CT)
17:00 – 17:25 V. Lozitsky: Magnetic fields and thermodynamical conditions at photospheric and chromospheric layers of X17.2/4B solar flare of 28 October 2003 (CT)
17:25 – 17:30 L. Le Phuong: Influence of variable gravity acceleration on Rayleigh-Taylor instability Northumbria University (P)
17:30 – 17:35 N. Kondrashova: Manifestation of a new magnetic flux emergence in the active region NOAA 11024 (P)
17:35 – 17:40 A. Attia: Analytical study of the fractional focused transport equation describing anomalous diffusion of energetic particles (P)
17:40 – 18:00 Discussion
19:00 ***Dinner, Opanas Restaurant***

Multi-scale plasma dynamic processes in the Sun-Earth system
Oral Session (Morning). Convener L. Kozak

09:00 – 09:35 Y. Fedorov: Solar cosmic ray kinetics in the interplanetary magnetic field (IT)
09:35 – 10:00 S. Gerasimenko: Influence of small-scale Bernstein turbulence on low-frequency plasma waves in pre-flare chromosphere of the Sun (CT)
10:00 – 10:30 B. Shakhov: Asymptotic Greens function for cosmic ray modulation problems (ICT)
10:30 – 10:55 L. Pustilnik: On non-universality of solar-terrestrial connections (CT)
10:55 – 11:00 S. Ivanov: Comparison of NARMAX, artificial neural network, and localized Lyapunov exponents for geomagnetic indices prediction (P)
11:00 – 11:30 ***Break, discussion and Poster Session***
11:30 – 11:55 V. Yatsenko: An optimization approach to space weather prediction: Robust NARMAX Model, Lyapunov exponents, predictability, and real-time algorithms (CT)
11:55 – 12:20 Y. Pavlenko: Activity of Proxima Cen. (CT)
12:20 – 12:45 A. Zalizovski: AGW/TID and sporadic ionospheric structures over the Antarctic peninsula. (CT)
12:45 – 12:55 Final words

12:30 ***Conference closed***

SESSION 1:

Dynamic processes in the Earth ionosphere and magnetosphere

Monday 28 August

MODELS OF THE ATMOSPHERIC GRAVITY WAVE-ELECTROMAGNETICS COUPLING AND PLANETARY ELECTROMAGNETIC WAVES IN THE IONOSPHERE: PROGRESS IN THE DEVELOPMENT

Y. Rapoport [1], V. Grimalsky [2], V. Fedun [3], V. Ivchenko [4], I. Ribalchenko [5], M. Hayakawa [6], A. Krankowski [7], Y. Selivanov [8], E. Tkachenko [9]

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In this talk, we will discuss a new seismo-ionospheric coupling model. In particular, we will discuss Atmospheric Gravity Wave (AGW) and Electromagnetics models (Rapoport, et al., 2006, 2017) and a possibility of their combination. This approach therefore, allows us to consider Very Low Frequency and Total Electron Content effects. We have found that Shannon entropy has the clear peculiarity in the same period as residual amplitude of VLF waves in the Earth-Ionosphere waveguide (see e.g. Solovieva M. et al., 2015), i.e. 3-4 days prior strong earthquake. This opens the way for the complex analysis of the electromagnetic pre-seismic events including VLF and TEC data. Direct measurements of the seismo-ionospheric impact and the corresponding "synergetic" characteristics, such as "phase-transition-like" entropy/information (Haken, 1991; De Santis et al.) were used.

The model of planetary electromagnetic waves (PEMW) in the atmosphere and the ionosphere has been developed without using the 'beta-plane' approximation. An influence of the geophysical conditions and initial perturbations on the characteristics of excited PEMW vortex structures has been investigated. PEMW are considered as a sensitive indicator of an influence on the ionosphere "from above" (from the solar wind and magnetosphere) and 'from below' (from seismogenic's processes, tsunamis and other powerful sources).

References.

De Santis A. et al. Bull. Seismolog. Soc. Amer., 101, 1386-1395, 2011

Haken H., Information and self-organization, Moscow, Mir (in Russian), 1991

Rapoport Yu. G. et al. Phys. Chem. Earth, 31, 437-446, 2006

Rapoport Yu. G.et al. Ann. Geophys., 35, 53-70, 2017

Solovieva M. et al. Ann. Geophysics 58, 5, A0552-1-7, 2015

THE POLARIZATION OF A CHARACTERISTIC ELECTROMAGNETIC WAVE IN IONOSPHERIC PLASMA

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In this study, we have calculated polarization ≠0) in ν of a characteristic wavefor the most basis conditions (B=B0z and ionosphere plasma. It could considerably say as results of findings that the wave polarization is harmonic with theoretical background. The most remarkable result is that the wave polarization has been showing the elliptical polarization for the accepted conditions.

IONOSPHERIC FOCUSING EFFECT IN METER-DECAMETER SOLAR OBSERVATIONS

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The Earth ionospheric irregularities can have natural focusing and defocusing effects on radio waves propagating from the Sun to the ground. This is due to the density variation of the irregularities which could act like convergent and divergent lenses on incident radiation. In solar radio astronomy, the focusing effect of emission from the Sun shows itself in form of specific spectral structures enhanced in intensities and appearing in solar low-frequency (meter and decameter wavelength ranges) dynamic spectra of radio telescopes. Such structures, known as Spectral Caustics (SCs), are considered to be the result of radio waves refraction on traveling ionospheric disturbances (TIDs). In this paper, we use the Nancay Decametric Array (NDA) data to carry out a statistical analysis of the SCs in solar dynamic spectra in meter-decameter wavelength range for a long period (17 years). On the basis of the statistical examination of the SCs, we found that the appearance of the SCs in dynamic spectra depends on the phase of the solar cycle. We also establish the seasonal dependence in the occurrence of the SCs. Since the SCs are believed to be caused by TIDs of medium scale (MSTIDs), this seasonal dependence can be related to the similar dependence in the appearance of MSTIDs. Besides, we present a broad family of spectral varieties of the SCs captured in solar dynamic spectra. Based on characteristic features in spectral morphology of all SCs, we introduce their classification on several types. The SCs can be ascribed to one specific aspect of solar-terrestrial relations.

ANALYSIS OF THE GEOMAGNETIC PULSATIONS DURING A SUBSTORM

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Generation of geomagnetic pulsations is a consequence of the development of magnetospheric and ionospheric plasma instabilities and generation of magnetohydrodynamic (MHD) waves. The connection between magnetosphere and ionosphere associated with the interaction of auroral particles and MHD waves and play important role in the dynamics of the magnetospheric disturbance. From a magnetospheric physics perspective the substorms is the key problems bounding together many physical processes and phenomena in the magnetosphere and ionosphere. Geomagnetic pulsations were studied on the basis of measurements the Earth's magnetic field fluctuations from satellites Cluster-2 (C1 and C2) mission for the event August 12, 2014 and measurements from ground-based magnetometers INTERMAGNET system - Amderma (Magnetic longitude 137.78, Magnetic Latitude 65.31), Abisko (101.82, 65.18) and Sodankyla (107.29, 63.81). There are some pulsations with a period of 4-10 minutes (Pc5) for ground-based measurements and Pi2 for satellites measurements among the obtained results [Kronberg et al, 2017; Kozak et al, 2017]. The work is done in the frame of the grant Az. 90 312 from the Volkswagen Foundation («VW-Stiftung»).

E. A. Kronberg, E. E. Grigorenko, D. L. Turner, P. W. Daly, Y. Khotyaintsev, L. Kozak Comparing and contrasting dispersionless injections at geosynchronous orbit during a substorm event // Journal of Geophysical Research – Space Physics DOI: 10.1002/2016JA023551 (2017), 18 p.

L.V. Kozak , A.T.Y. Lui , E.A. Kronberg , A.S. Prokhorenkov Turbulent processes in Earth's magnetosheath by Cluster mission measurements // Journal of Atmospheric and Solar–Terrestrial Physics 154 (2017) 115–126

THE LOSS-TANGENT TENSOR FOR IONOSPHERE PLASMA IN NORTHERN HEMISPHERE

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In this study, we have calculated trace matrix of the loss- tangent tensor for ionosphere plasma by using the real geometry of Earth's magnetic field for in northern hemisphere according to geographic latitude and local time. It could considerably say as results of findings that the diagonal elements of loss-tangent are same phase externally applied electric field while other elements are vibrate in opposite phase for the accepted conditions. The most remarkable result is that the trace matrix elements for loss-tangent tensor around equator at 1200 LT are minimum and they have seasonally sharp ups/downs with geographic latitudes at 2400 LT. Besides, the change of the trace matrix elements of loss-tangent with local time for all seasons is very interest and complex especially for mid-latitude and high-latitude.

ON THE DETERMINATION OF TURBULENT ENERGY DISSIPATION RATE FROM SPORADIC-E PARAMETERS IN THE LOWER IONOSPHERE

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Atmosphereic turbulence plays an important role in dynamics of the lower ionosphere. Above an altitude of 80 km a source of the turbulence may be destruction of the atmospheric gravity waves and tides propagating from the lower atmospheric layers and also the nonlinear interaction of planetary waves and tides. These large-scale atmospheric motions are responsible for a vertical shear of the neutral wind that is necessary for the production of mid-latitude-type sporadic-E (though such layers are observed at auroral latitudes and even near the magnetic equator). The sporadic-E may be considered as a bright example of the ionosphere-atmosphere interaction. If the sporadic-E height is below the homopause, the turbulence exerts an essential influence on sporadic-E parameters. Therefore, parameters of the turbulence can be determined from the sporadic-E ones. A fundamental parameter of turbulence is the mean rate of turbulent energy dissipation. Determination of the rate from sporadic-E parameters is the purpose of this report. To obtain an expression that connects the dissipation rate with sporadic-E parameters, the results of sporadic-E wind-shear theory and the Richardson–Obukhov law for turbulent diffusion are used. The derived formula permits to determine the turbulent energy dissipation rate if one knows the sporadic-E thickness, the Hall parameter for ions in the plasma layer, and measurable parameters of the vertical shear in neutral wind that produced sporadic-E.

OSCILLATIONS OF ULF WAVES IN THE EARTH'S MAGNETOSPHERE

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Ultralow-frequency (ULF) waves in the Earth's magnetosphere are regularly detected by groundbased magnetometers, radars, and satellites. The importance of these waves for the physics of the magnetosphere is determined by their capability to accelerate charged particles to relativistic energies and to serve as triggers of magnetospheric substorms and means for magnetosphere diagnosis. The one-dimensional inhomogeneous cylindrical model of the magnetosphere is often used for the study of ULF waves with large azimuthal wave numbers. This model significantly simplifies the differential equations of small oscillations for azimuthally small-scale perturbations and permit a fairly complete investigation of their cross-section (towards the magnetic field) structure in the local approximation. However, it remains an open question of the conditions of applicability of the cylindrical model of the magnetosphere. In the present work it is shown that the model of a radially inhomogeneous plasma cylinder adequately describes the ULF perturbations in the Earth's magnetosphere. Also, an equation of small oscillations of the ULF-mod was obtained. It is shown that this equation takes into account the fast magnetic wave, which is typical for open magnetospheric system. It was found that the appearance of the fast magnetic waves in the magnetospheric plasma leads to the generation of Alfvén waves with discrete spectrum. This result confirms that these modes are generated near the peak of the Alfvén frequency. In addition, was shown that the discrete Alfvén modes are also generated
near the minimum of Alfvén frequency.

The work is done in the frame of the grant Az. 90 312 from the Volkswagen Foundation («VW-Stiftung»).

S.O. Cheremnykh, I.T. Zhuk. Discrete ULF modes in the Earth's magnetosphere near the Alfven frequency minimum. Kinematics and Physics of Celestial Bodies, 2017, Vol. 33, No. 1, pp.13–23.

ROLE OF WAVES IN MAGNETIC RECONNECTION AT EARTH'S MAGNETOPAUSE: MMS OBSERVATIONS

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The role of waves in magnetic reconnection remains an outstanding question. Waves can produce particle heating and acceleration, cross-field particle diffusion, and anomalous resistively; all of which can impact ongoing reconnection. We investigate the waves that develop near the electron and ion diffusion regions of asymmetric reconnection at Earth's magnetopause using the Magnetospheric Multiscale (MMS) spacecraft. In particular, we show that near the stagnation point intense lower hybrid drift waves are produced, which result in cross-field particle diffusion, broadening the density gradient.
We also show that agyrotropic beams generated in electron diffusion regions can become unstable to high-frequency electrostatic waves. These waves are sufficiently large to thermalize the beam, potentially modifying the electron dynamics near electron diffusion regions. We discuss how these waves can affect ongoing magnetic reconnection.

CASCADE PROCESSES IN THE EARTH MAGNETOSPHERE

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Interaction of solar wind with the Earth's magnetosphere leads to an exchange of matter and transition of energy and momentum, which affects near-space conditions. This gives rise to a three-dimensional current system and generates large-scale electric fields. Satellite experiments indicate that the boundary magnetospheric regions play a special role in the transformation of the solar wind kinetic energy into charged particle and electromagnetic field energy within the magnetosphere. Our study devoted to analysis of the processes in the transition layer of the Earth's magnetosphere from the measurement of satellite mission Cluster-2. Within the framework of the research, a spectral and multifractal analysis (analysis of higher order power law of structure function) was conducted. As a result of wavelet analysis both characteristic frequencies and cascade processes (direct – refer to the transfer of energy from large timescales to the small timescales; and inverse – refer to the transfer of energy from small timescales to the large timescales). Herewith, in the transition from solar wind to foreshock region inverse cascade processes occur more often than direct [Kozak et al, 2017]. Thus, the magnetosphere behaves like a self-organizing system with different characteristic scales.

The work is done in the the framework of the educational program No.2201250 «Education, Training of students, PhD students, scientific and pedagogical staff abroad» launched by the Ministry of Education and Science of Ukraine

L.V. Kozak , A.T.Y. Lui , E.A. Kronberg , A.S. Prokhorenkov Turbulent processes in Earth's magnetosheath by Cluster mission measurements Journal of Atmospheric and Solar–Terrestrial Physics 154 (2017) 115–126

THE TURBULENCE PROCESSES IN THE EARTH MAGNETOTAIL

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Turbulence is the natural state of the cosmic plasma; therefore, studying its characteristics is essential for the understanding of the fundamental properties of nature. In magnetohydrodynamics, the properties of turbulence can be dramatically affected both by flow boundaries and the scales of the structures (waves, vortices, etc.) formed by magnetic and electric fields. The turbulence of plasma flows can be generated by many classes of instabilities: drift dissipative, kinetic, magnetohydrodynamic, etc. In addition, the turbulence is characterized by a large number of degrees of freedom and nonlinearly interacting modes. Scientists typically use statistical physics and the theory of probability to describe such a medium. This way they can obtain information about average variations in the macroscopic parameters of the plasma medium in time (or space) without scrutinizing the conditions of excitation of specific nonlinear processes. In this work, we address the features of turbulent processes in the magnetospheric tail.

The analysis of magnetic field fluctuations in the tail of the magnetosphere at various spatial and temporal scales for the events (2005, 2015) observed by the Cluster-2 missions was carried out. Multiracial analysis, spectral and wavelet analysis was done. The features of the turbulent processes on the different time scales were obtained. Moreover, the temporal profiles of the time dependence of the fluctuation power for the gyrofrequencies of hydrogen, oxygen, and helium ions are established.

The work is done in the frame of the grant Az. 90 312 from the Volkswagen Foundation («VW-Stiftung»).

ANALYSIS OF THE TURBULENT PROCESSES IN GEOSPACE

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Methods and approaches that can be used for analyzing the hydrodynamic and magnetohydrodynamic turbulent flows are proposed. It is shown that the best methods to characterize the types of turbulent processes are the methods of the statistical physics. Within the statistical approach the fractal analysis (determination of the fractal length and height of the maximum of the probability density fluctuations of the studied parameters) and the multifractal analysis (study of a power dependence of high order statistical moments and construction multifractal spectrum) had been carried out [Kozak et al, 2017]. It is indicated that the statistical analysis of properties of turbulent processes can be supplemented by the spectral studies: Fourier and wavelet analysis. In order to test the methods and approaches we have used the magnetic field measurements from the space mission Cluster-II with a sampling frequency of 22.5 Hz in different regions of Earth's magnetosphere and solar wind plasma [Kozak et al, 2017].

The evolution of maximum of probability density function and the structure functions of different orders as characteristics of turbulent processes for different time scales are investigated. Structure functions of high orders are used to determine the character of turbulent processes and the resulting diffusion in these regions. We have found that the highest intermittency is observed in the postshock region. Furthermore, the magnetic turbulence in the middle magnetosheath corresponds to log-Poisson turbulent cascade model, and that in the SW
plasma conforms with the Iroshnikov-Kraichnan`s model. A good agreement between the investigations and the mutual additions to provide an overall view for the turbulence can be noted.

The work is done in the framework of the educational program No.2201250 «Education, Training of students, PhD students, scientific and pedagogical staff abroad» launched by the Ministry of Education and Science of Ukraine; in the frame of the grant Az. 90 312 from the Volkswagen Foundation.

L.V. Kozak , A.T.Y. Lui , E.A. Kronberg , A.S. Prokhorenkov Turbulent processes in Earth's magnetosheath by Cluster mission measurements Journal of Atmospheric and Solar–Terrestrial Physics 154 (2017) 115–126

ASPIICS SPACEBORNE CORONAGRAPH

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ASPIICS – "Association of Spacecraft for Polarimetric and Imaging Investigation of the Corona of the Sun" – is a novel solar white-light coronagraph that will be launched onboard the PROBA-3 mission. PROBA-3 is a technological ESA mission to demonstrate high precision flying formation (FF). ASPIICS utilizes this opportunity to build a giant – 150 m baselong coronagraph. The first satellite will carry a 1.5 m diameter external occulter (EO) ahead of the second satellite, which will carry optical telescope with its entrance aperture positioned precisely in the shadow of the EO. The basic idea for the ASPIICS optical layout is to provide observations up to the heights of 3 R_{Sun} with the minimal possible height of obscuration (below 1.1 R_{Sun}). Observations will be carried out in 6 bandpasses, selected by filters: wide-band (30 nm) filter centered on 550 nm, two narrow-band (2 nm) centered on Fe XIV 530 nm and He I D3 588 nm, 3 polarizers with wide-band filters.
The biggest technical challenge for the instrument is the suppression of high amount of diffracted light in the region of geometrical shadow of EO. The level of light strongly depends on relative sizes of external and internal occulters. Thus the currently considered minimum height of 1.1 R_{Sun} is a tradeoff between our desire to observe solar corona close to the photosphere and the level of straylight.
In the talk we will consider scientific tasks and main features of PROBA-3/ASPIICS, its optical performance, achievable minimal height of observation, compare it with other coronagraphs.

STUDY OF NONLINEAR EVOLUTION OF DISPERSIVE ALFVEN WAVES AND DRIVEN PLASMA TURBULENCE IN SOLAR WIND

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Plasma is the most abundant state of ordinary matter in the universe and it is often turbulent. Alfven waves, discovered some four decades ago, are ubiquitous in magnetized/space plasmas. The ubiquitous Alfven waves can cause numerous nonlinear processes in the interplanetary space. The observed solar wind power spectrum reports a breakpoint near ion length scales. Presently, we have studied the small scale solar wind turbulence with dispersive Alfven waves undergoing transverse collapse as the driver. In this paper efforts have been made to study the evolution of filamentation instability introduced by dispersive Alfven waves. This instability is reported to occur for the case of dispersive Alfvén wave (DAW) propagating parallel to ambient magnetic field. Here, we consider a plane wave superimposed with periodic perturbation in intensity such that due to non-uniformity of the perturbation a finite intensity gradient arises and gives rise to ponderomotive force. Numerical simulation is carried out and the wave localization is studied by varying parameters of the pump and perturbation. The power spectral density shows steepening at small scales. The spectral index accounting for energy transfer varies from being flat to steep with the stronger pump.

ON A ROLE OF QUADRUPLE COMPONENT OF MAGNETIC FIELD IN DEFINING SOLAR ACTIVITY IN GRAND CYCLES

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The aim of this work is revise our prediction of solar activity using a solar background magnetic field as a proxy by the inclusion of eigen vectors of solar magnetic waves produced by quadruple magnetic sources, in addition to the principal eigen modes generated by two-layer dipole sources (Zharkova et al., 2015). By considering the interference of two dipole and one quadruple waves we produce the revised summary curve for the last 400 years accounting for the additional minima of solar activity occurred at the beginning of 19th (Dalton minimum) and 20th centuries. Using the dynamo model with meridional circulation and selecting the directions of circulation for quadruple waves, we estimate the parameters of quadrupole waves best fitting the observations in the past grand cycle. The comparison shows that the quadruple wave has to be generated in the inner layer of the solar convective zone, in order to provide the additional minima observed in 19 and 20 centuries, thus, naturally accounting for Gleissberg centennial cycle. The summary dynamo wave simulated for the dipole and quadruple sources reveals much closer correspondence of the resulting summary curve derived from the principal components of magnetic field variations to the solar activity oscillations derived from the average sunspot numbers in the current grand cycle.

SESSION 2:

MHD waves – coupling between lower solar atmosphere and solar corona (observations, theory, numerics)

Tuesday, 29 August

NONLINEAR PLASMA PROCESSES IN PARTIALLY IONIZED PLASMAS

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In the present study we investigate the generation, propagation and nature of nonlinear waves in a partially ionised plasmas we can meet in the lower part of the solar atmosphere. In our analysis the nonlinear growth of waves is balanced by dissipation and/or dispersion. In particular, we will investigate the solutions of various nonlinear waves equations (KdV, Burgers, etc.) describing the propagation of solitons and shocks. Special attention will be paid to the effect of neutrals in the plasma, and investigate how transport mechanisms such as ambipolar diffusion will influence the development and evolution of these waves.

DO PHOTOSPHERIC NON-MAGNETIC BRIGHT POINTS EXIST?

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Recent high-resolution simulations of non-magnetic solar photopheric convection suggest presence of a separate class of small-scale photospheric brightenings, which coincide with intergranular vortex tubes. In contrast to well-known magnetic bright points, these brightenings and are not related to magnetic fields. In our presentation, using high-resolution simulations with MURaM and detailed radiative diagnostics of the simulated models, I will analyse the physical characteristics of these brightenings and their observability with current and future instruments for solar observations.

MAGNETOACOUSTIC WAVES AND THE KELVIN—HELMHOLTZ INSTABILITY IN A STEADY ASYMMETRIC SLAB

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Recent observations have shown that bulk flow motions in structured solar plasmas, most evidently in coronal mass ejections, may lead to the formation of Kelvin-Helmholtz instabilities (KHI). Analytical models are thus essential in understanding both how the flows affect the propagation of magnetohydrodynamic (MHD) waves, and what the critical flow speed is for the formation of the KHI. We investigate both these aspects in a novel way: in a steady magnetic slab embedded in an asymmetric environment. The exterior of the slab is defined as having different equilibrium values of the background density, pressure and magnetic field on either side. A steady flow and constant magnetic field are present in the slab interior. General solutions and the KHI threshold values are obtained numerically. It is shown that, generally, both the KHI threshold and the cut-off frequencies for magnetoacoustic waves are lowered by the asymmetry.

KINK MODE IN MAGNETIC TUBE WITH DISCONTINUOUS MAGNETIC FIELD

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The conditions of realisation and stability of kink modes with azimuthal wave numbers m=±1 in cylindrical plasma flex with twisted magnetic field and homogeneous current along its axis have been investigated. It has been assumed the existence of permanent vertical magnetic field both inside and outside the flex tube, which is surrounded by currentless plasma. It was supposed that azimuthal magnetic field decreases inversely proportional to the distance from the border of the flex. Dispersion relations for stable and unstable modes in approximation of 'thin' plasma flex have been obtained. The analyses of these equations has been provided for the case of discontinuous vertical magnetic field on the flex's boundary. The conditions of propagation of wave modes have been defined. It was found, that unstable modes with m=±1 can not be realised. The results can be applied for the interpretation of behavior of solar magnetic tubes using the measurements provided by the spacecrafts.

Reference

O.K. Cheremnykh, A.N. Kryshtal, A.A. Tkachenko, Kink mode m=1 in magnetic tube with discontinuous magnetic field, Advances in Space Research, (doi.org/10.1016/j.asr.2017.05.026).

MAGNETIC FIELDS OF THE QUIET SUN. WHAT DO WE KNOW ABOUT THEM ?

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At first, we present investigations aimed at determining the magnetization of the quiet Sun photosphere from the Hanle effect in atomic and molecular lines. These investigations indicate that the bulk of the quiet solar photosphere is significantly magnetized, due to the ubiquitous presence of an unresolved magnetic field with an average strength about 100 G. The ensuing magnetic energy density is so significant that the energy flux turns out to be substantially larger than that required to balance the chromospheric energy losses.

Secondly, we provide a review on the quiet Sun magnetic fields seen by the «Zeeman eyes». We pay special attention to the spectral region around 1083.0 nm. It is a powerful diagnostic window which contains information coming simultaneously from the chromosphere (He I 1083.0 nm triplet) and from the photosphere (Si I at 1082.7 nm). We present results of the magnetograph-like analysis of the latter line. We show that the longitudinal component of the field derived using Si I 1082.7 nm line correlates remarkably well with the vertical component of the small-scale magnetic fields in the quiet solar middle photosphere.

DISSIPATION OF ALFVEN WAVES THROUGH ION-NEUTRAL INTERACTIONS

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We investigate the ability of ion-neutral interactions to dissipate Alfven waves in the solar chromosphere. An acoustic driver is used to generate perturbations in a self-similar magnetohydrostatic flux tube model. As these waves travel into the center of the magnetic field concentration, significant energy is dissipated, a factor of 20 higher than the dissipation of static currents. This heating is caused by the damping of magnetic waves, as seen by a decrease in Poynting flux when ambipolar diffusion is included. The dependence of this energy dissipation with resolution, driver amplitude and frequency is studied.

SUNSPOT STUDIES WITH THE NEW SOLAR TELESCOPE AT THE BIG BEAR SOLAR OBSERVATORY

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In this talk I will introduce the 1.6 meter New Solar Telescope (NST) that is operating at the Big Bear Solar Observatory in California. The presentation will also briefly review several studies performed by the NST team that are focused on fine-scale structures of sunspots, which include moving magnetic features, Ellerman bombs, formation of sunspot penumbra and waves, sunspot evolution, a white light flare, and small-scale dynamics in the penumbra. I will also present new data on propagation of sunspot waves and magnetic field dynamics in sunspot light bridges.

OBSERVATIONAL SIGNATURES OF A KINK-UNSTABLE CORONAL FLUX ROPE USING HINODE/EIS

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The signatures of energy release and energy transport for a kink-unstable coronal flux rope are investigated via forward modelling. Synthetic intensity maps are generated from a 3D numerical simulation. The CHIANTI database is used to compute intensities for three Hinode/EIS emission lines that cover the thermal range of the loop. The intensities at simulation resolution are spatially degraded to the Hinode/EIS pixel size (1”), convolved using a Gaussian point-spread function (3”), and exposed for a characteristic time of 50 seconds. The synthetic images generated for rasters (moving slit) and sit-and-stare (stationary slit) are analysed to find the signatures of the twisted flux and the associated instability. We find that there are several qualities of a kink-unstable coronal flux rope that can be detected observationally using Hinode/EIS, namely the growth of the loop radius and the increase in intensity towards the radial edge of the loop. However, EIS cannot resolve the small, transient features present in the simulation, such as sites of small-scale reconnection.

PROGRESS TOWARDS LAGRANGIAN MODELING OF SOLAR WIND PROPAGATION IN THE HELIOSPHERE

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We report recent progress in the development of a new Lagrangian magnetohydrodynamic particle-in-cell solver, Slurm. Slurm is the first ever particle-based MHD code specially designed to study CME and shock propagation in the heliosphere. We have implemented advection of the electromagnetic potential by fluid particles, which has shown extremely low diffusion of the magnetic flux. Our implementation of open boudary conditions is very efficient (for a particle code) because data structures used to handle particles allow for fast item removal and insertion. Finally, our code supports different geometries, which is demonstrated by comparison of test simulations in cylindrical and Cartesian coordinates. Combination of three ingredients: magnetic flux conservation, efficient particle handling, and support of generalized coordinates, makes Slurm a perfect tool for modeling solar wind and CME propagation in the heliosphere.

SPECTRAL INVERSION OF THE HALPHA AND CA II 8542 A LINES OBSERVED BY SST/CRISP IN CHROMOSPHERIC JETS

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We present results of spectral inversion of the Halpha and Ca II 8542 A lines observed by the imaging spectropolarimeter CRISP at the Swedish 1-m Solar Telescope in chromospheric jets identified in the quiet-Sun atmosphere. The inversion aims to reveal increased turbulence in these jets as a possible consequence of Kelvin-Helmholtz instabilities expected for strongly-sheared plasma flows at jet interfaces. To verify the results physical parameters of the chromospheric jets are inferred by different variants of cloud model inversion technique. The cloud model parameters of the chromospheric jets are supplemented by their lifetimes, widths, maximum lengths, apparent longitudinal velocities, ransversal displacements, and transversal velocities to compare them with parameters of Rapid blueshifted events.

FAST MAGNETOHYDRODYNAMIC CNOIDAL WAVES AND SOLITONS IN ELECTRON-POSITRON PLASMA

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Using the multi-fluid magnetohydrodynamic model linear and nonlinear propagation of fast magnetoacoustic waves is investigated in homogeneous and warm, collisionless electron-positron plasma. By means of reductive perturbation method, Korteweg-de Vries equation is derived under the appropriate boundary conditions.The cnoidal wave and soliton solutions are obtained using Sagdeev potential approach for magnetoacoustic wave propagation in the direction perpendicular to the external magnetic field. The numerical illustration of magnetoacoustic cnoidal waves and solitons is also presented by using the parameters of astrophysical plasmas.

GIANT PROMINENCE ERUPTION ASSOCIATED WITH FAST CME

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We have carried out the analysis of dynamic prominence eruption observed on 2014 September 26 on the south-east limb of the Sun from ARIES, Nainital in H-alpha. It was very energetic giant prominence eruption and the twisted bundle of flux ropes erupts beyond the LASCO C3 field-of-view. It is associated with a fast Coronal Mass Ejection (CME) with the speed of 1469 km/s. Most of the prominence material erupted but partially falls over the surface of Sun. The height obtained by the CME in LASCO is approx. 30 R_sun. and the average speed in H-alpha approx. 550 km/s. The event was well observed in H-alpha from ARIES and space-based missions like SDO, STEREO, LASCO, Nobeyama etc. We discuss this prominence eruption in the light of existing theories and it fulfills the criteria of kink instability and tether-cutting model.

A BEGINNERS GUIDE TO THE DKIST CRITICAL SCIENCE PLAN

E. Scullion
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The 4-m class Daniel K Inouye Solar Telescope (DKIST) will be the most powerful ground-based solar telescope ever built and will be capable of observing the solar photosphere at an incredible resolution of 0.022 arcsec (~16 km) at 430.5 nm (blue channel). DKIST will host a number of advanced instruments, namely, the Visible Broadband Imager (VBI), the Visible Tunable Filter (VTF), the Visible Spectro-Polarimeter (ViSP), Diffraction Limited-Near Infra-Red Spectro-Polarimeter (DL-NIRSP) and the Cryogenic-Near Infra-Red Spectro-Polarimeter (Cryo-NIRSP). Various combinations of these instruments are able to perform simultaneous measurements of the photosphere and chromosphere, via interferometric and spectro-polarimetric imaging, as well as, coronagraphic observing for far off-limb diagnostics of coronal loops and prominences. The potential for ground-breaking solar science is wide-ranging. Prior to first light observations in 2020, the DKIST project seeks community input in the form of a Critical Science Plan (CSP). The CSP will consist of a list of Science-Use-Cases (SUCs) that demonstrate the best use of the instrumentation suite to achieve high impact science within 5 designated Research Areas. The community-led science proposals will be ranked and run at first light. As a member of the DKIST Science Working Group I am charged with the task of engaging with the global solar community in the development of the CSP and application of SUCs in the online submission portal. This talk will be the "what, why, when and how" to turn your science idea into DKIST observations.

5 MHD METHODS FOR CORONAL LOOPS

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Countless methods have been developed to model coronal loops, each with their own assumptions, advantages and disadvantages. How certain can we be that our chosen approach is valid? How do we know when it is no longer valid? Here we aim to emphasize how important these questions are.

We take five methods for modelling coronal loops: full MHD, magneto-frictional relaxation, 1D approach, linearisation and Reduced MHD and apply each to the case of a coronal loop undergoing footpoint displacement. Full MHD is taken to be the exact solution and the other methods are compared to it. Different values of plasma beta and displacement are tested.

The important thing to remember is to be very careful what you assume!

SESSION 3:

General solar activity in the Sun and heliosphere

Wednesday, 30 August

REINFORCING THE DOUBLE DYNAMO MODEL WITH SOLAR-TERRESTRIAL ACTIVITY IN THE PAST THREE MILLENNIA

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Using a summary curve of two eigen vectors of solar magnetic field oscillations derived with Principal Components Analysis (PCA) from synoptic maps for solar cycles 21-24 as a proxy of solar activity, we extrapolate this curve backwards three millennia revealing 9 grand cycles lasting 350-400 years each. The summary curve shows a remarkable resemblance to the past sunspot and terrestrial activity: grand minima - Maunder Minimum (1645-1715 AD), Wolf minimum (1280-1350 AD), Oort minimum (1010-1050 AD) and Homer minimum (800-900 BC); grand maxima - modern warm period (1990-2015), medieval warm period (900-1200 AD), Roman warm period (400-10 BC) and others. We verify the extrapolated activity curve by the pre-telescope observations of large sunspots with naked eye, by comparing the observed and simulated butterfly diagrams for Maunder Minimum (MM), by a maximum of the terrestrial temperature and extremely intense terrestrial auroras seen in the past grand cycle occurred in 14-16 centuries. We confirm the occurrence of upcoming Modern grand minimum in 2020-2053, which will have a shorter duration (3 cycles) and, thus, higher solar activity compared to MM. We argue that Sporer minimum (1450-1550) derived from the increased abundances of isotopes ^{14}C and ^{10}Be is likely produced by a strong increase of the terrestrial background radiation caused by the galactic cosmic rays of a powerful supernova.

LONG-TERM VARIATIONS OF THE QUIET SUN WITH 11-YEAR CYCLE OF SOLAR ACTIVITY

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We report on monitoring of solar lines long-term variations using the horizontal solar telescope ATsU-5 of the Main Astronomical Observatory of the National Academy of Sciences of Ukraine. The aim of the monitoring is to study how the physical parameters of the quiet solar atmosphere change over the last 11-year solar cycle. The high precision metrological stability of the ATsU-5 telescope makes it possible to measure the slightest temporal changes of the solar spectral line parameters such as line depth, equivalent width, full width at half maximum, and bisector curvature. We find that during 2012-2017 the line core depth and full width at half maximum of the many solar spectral lines show response to the cycle modulation of the total unsigned magnetic field of the Sun. The behavior of these line parameters can be explained by variations of the temperature and convective motions of the quiet photosphere with 11-year cycle of solar activity.

SUN'S MAGNETIC FIELD REVERSAL IN CYCLE 24

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The Sun is a magnetic star with large and complex magnetic field. The basic shape of the Sun's magnetic field is a field of a simple bar magnet. The dipole component changes value and sign every 11-year solar cycle forming the 22-year magnetic cycle. Polar field reversals occur near maxima of solar activity. We investigated the reversal of solar magnetic field in cycle 24 analyzing the dynamics of high-latitude solar magnetic fields separately in northern and southern hemispheres. Solar polar field strength measurements from the Wilcox Solar Observatory and low-resolution synoptic magnetic maps from the SOLIS project and from Helioseismic and Magnetic Imager (HMI) onboard Solar Dynamics Observatory were used. We analyzed total magnetic flux at near-polar zones, starting from 55, 60, 65, 70, 75, 80 and 85 degrees of latitude, and found time points when the total magnetic flux changed its sign.It was found that the total magnetic flux changed its sign from negative to positive in the N-hemisphere and vice versa from positive to negative in the S-hemisphere. These changes occurred first at lower latitudes and finally near the poles. The polarity reversal was single in the S-hemisphere and three-fold in the N-hemisphere. The process of polarity reversal in the S-hemisphere and first reversal in the N-hemisphere were gradual when it moves from zones of ≥|55|° to poles during 7 CRs to 2 years. The second and third polarity reversals in the N-hemisphere were fleeting and covered all the zones nearly simultaneously. Polarity reversal in the N-hemisphere was completed by May 2014, roughly one year earlier than in the S-hemisphere. Polar magnetic field reversals finished in northern and southern hemispheres approximately by CR 2150 and CR 2162, respectively.

PRELIMINARY PREDICTION OF SOLAR CYCLE 25

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Solar cycle 24 will end in some years. What level of solar activity will be in the next cycle? Here we attempted to answer to this question. We analyzed international monthly sunspot numbers revisited in 2015. The correlation between various parameters of solar cycles 1–24 was investigated. Correlation coefficients were calculated and corresponding regression equations were obtained. Solar cycle 25 was predicted using the regression equations. It is expected that solar cycle 25 will be slightly stronger than cycle 24: its amplitude will be approximately 160 (or 105 in 'old' units, before the revision), maximum of solar cycle 25 will occur in the beginning of 2025. Solar cycle 25 will start in May 2020 with sunspot number of 8 in its minimum.

DOUBLE MAXIMUM OF SOLAR CYCLE

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We propose a scenario to explain the observed phenomenon of double maximum of sunspot cycle, including the generation of the magnetic field near the bottom of the solar convection zone (SCZ) and its subsequent removal from the deep layers to the surface in “the royal zone». There are five processes involved in reconstructing of the magnetic field during a cycle, namely: the omega-effect, meridional circulation, magnetic buoyancy, macroscopic turbulent diamagnetism and magnetic pumping due to matter density inhomogeneity (the MPDI-effect). It was found that the reconstruction of magnetism in the near-polar and the near-equatorial domains of the SCZ occurs in different regimes. It is due to different conditions for the MPDI effect in the polar and equatorial domains. A key role in the proposed mechanism of two-humped maximum is played by two waves of toroidal fields moving from the lower base of the SCZ (tachocline) to the solar surface in the equatorial domain. At the beginning of a cycle, the deep radial differential rotation generates a strong toroidal field near tachocline by affecting the poloidal field of the previous cycle (the omega effect). In the near-equatorial domain, magnetic buoyancy, turbulent diamagnetism, and the MPDI-effect act together to transport the deep toroidal field to the solar surface, where its fragments can be observed after a while as bipolar sunspot groups at the middle latitudes of “the royal zone”. This upward directed first wave of toroidal fields is responsible for the main maximum of sunspot activity. However, the underlying toroidal fields in the high-latitude polar domains are blocked at the beginning of the cycle near the SCZ bottom by two “negative buoyancy” effects: the downward turbulent diamagnetic transfer and the downward magnetic pumping due to density inhomogeneity. It is only 1–2 years after, when the deep equatorward meridional flow will push these fields into low-latitude areas of the near-equatorial domain (where there are favourable conditions for rise of fields, because here transfer caused by magnetic pumping due to density inhomogeneity is directed upward), these belated fields rise to the surface (the second wave of toroidal fields). These second batch of belated toroidal fields come to the surface at somewhat lower latitudes and produce the repeated maximum of sunspot activity.

ON THE PROPAGATION OF TRANSVERSE WAVES ALONG THIN GRAVITY STRATIFIED MAGNETIC FLUX TUBES IN THE LOWER SOLAR ATMOSPHERE

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Different methods are used for description of linear transverse (kink) modes in thin magnetic flux tubes embedded in a stratified medium. The most popular one is related to the elastic thread model elaborated by Spruit (1981). The new approach which is based on the Taylor and Laurent series expansion of wave variables with respect to the tube radius inside and outside of the magnetic flux tube was proposed by Lopin and Nagorny (2013). As a result, different dispersion relations for kink modes have been found. It has been shown that main reason of this discrepancy is explained by the incorrect phenomenological equation of plasma motion proposed by Spruit (1981) while contribution of the radial component of the magnetic flux tube is negligible (Lopin et al., 2014). This suggests that some results obtained by Spruit (1981) should be revised.

VERY HIGH FREQUENCY TEMPERATURE SPECTRUM IN THE SOLAR WIND

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We study recently measured density, temperature and velocity spectrum in the solar wind. Recent high frequency spectra were derived on the assumption of temperature isotropy. We show that with this assumption measured high frequency spectrum is strongly affected by magnetic field perturbations.

This work has been supported by Shota Rustaveli National Science Foundation grants FR/51/6-300/14 and FR/516/6-300/14.

SESSION 4:

MHD waves – coupling between lower solar atmosphere and solar corona (observations, theory, numerics)

Thursday, 31 August

SO, WHAT IS A SUNQUAKE?

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Using local helioseismology, we study the acoustic emission from near-surface layers in the photosphere: quiet Sun, flaring and non-flaring active regions and place the results in the context of known and new sunquakes.

BEAM ELECTRONS AS A SOURCE OF BALMER AND PASCHEN EMISSION IN SOLAR FLARES

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There are rapid increases of hard and soft X-rays (HXR) and ultra-violet emission with large Doppler blue-shifts associated with plasma upflows observed at flare onsets accompanied by increases in white light emission and in H_α hydrogen emission with large red-shifts of 1–4 Å observed with various past (Ichimoto and Kurokawa, 1984, Wuelser and Marti, 1989) and current (the Swedish Solar Telescope, SST) instruments (Druett et al., 2017). These effects point to fast effective sources of excitation and ionisation of hydrogen atoms in flaring atmospheres associated with HXR emission. Most current radiative hydrodynamic models can account for SXR and UV emission but fail to explain correctly the strongly red-shifted H_α line emission occurring at the flare onsets.

In this paper we investigate electron beams as the agents accounting for the observed hydrogen line and continuum emission by considering a 1D hydrodynamic response of the quiet sun chromosphere to injection of an electron beam and its conversion into a flaring atmosphere with its own kinetic temperatures, densities and macrovelocities (Zharkova and Zharkov, 2007). A radiative response in these atmospheres is simulated using a fully non-local thermodynamic equilibrium (NLTE) approach for a 5 levels plus continuum hydrogen atom model, considering its excitation and ionisation by external and internal diffusive radiation and by inelastic collisions with thermal and beam electrons. (Druett et al.,2017).The hydrodynamic model is shown to account closely for the timing and magnitude of upward motion to the corona observed in 171 Å by the Atmospheric Imaging Assembly/Solar Dynamics Observatory for C1.5 flaring event onset (Druett et al., 2017). Moreover, inelastic collisions with beam electrons are shown to strongly increase excitation and ionisation of hydrogen atoms at all depths from the chromosphere to photosphere. This leads to an increase in Lyman continuum radiation, which governs the hydrogen ionisation and leads to strong enhancement of emission in Balmer and Paschen continua. The contribution functions for Paschen continuum emission indicate a close correlation of the emission induced by electron beams with the observations of heights of WL and HXR emission reported for limb flares. This process also leads to a strong increase of wing emission (Stark's wings) in Balmer and Paschen lines combined with large red-shifted enhancements of H_α line emission resulting from a downward motion by hydrodynamic shocks. The simulations reproduce very closely the observed H_α line profiles with large red-shifts in a C1.5 flare by the Swedish Solar Telescope (Druett et al, 2017), the large red-shifts previously observed (Ichimoto and Kurokawa, 1984, Wuelser and Mari, 1989) and explains dimming of H_α emission at flare onsets if observed with narrow spectral windows of 2-3 Å.

Druett, M. et al. Beam electrons as a source of H-a flare ribbons. Nat. Commun. 8, 15905
doi: 10.1038/ncomms15905 (2017)

JET FORMATION IN SOLAR ATMOSPHERE: 2-3D NUMERICAL STUDY

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Using numerical resistive MHD simulations, we have shown that jets with features of type II spicules and cool coronal jets corresponding to temperatures of 10^4 K can be formed due to magnetic reconnection. In the 2D simulation we used two complex magnetic configurations: (i) a symmetric case, i.e. when the magnetic field strength of the two neighboring magnetic loops is equal and (ii) an asymmetric case when magnetic strength of loops is different. In the case (i), the excited jets rise vertically, whereas in the case of an asymmetric configuration (ii) the jet shows an inclination, which depends on the magnetic field strength ratio of the two loops and the distance between them. In the 3D simulation the magnetic configuration corresponds to a 3D potential magnetic field extrapolated from a dynamic realistic MHD simulation of solar photospheric magnetoconvection, which is mimicking quiet-Sun. We have found that formation of the jets is dominated by the Lorentz force, which helps to collimate and accelerate the plasma upwards. Analyzing various properties of the jet dynamics, we found that the jet structure shows significant asymmetric Doppler shift near to regions with high vorticity. The morphology, upward velocity, covering a range up to 100 km/s, and life-time of the structure is more than 100 s, are similar to those expected for type II spicules.

COLLECTIVE MHD WAVES IN SOLAR CORONAL STRUCTURES WITH CONTINUOUS TRANSVERSE STRUCTURING: THEORIES AND SEISMOLOGICAL APPLICATIONS

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Low-frequency waves and oscillations in the magnetohydrodynamic (MHD) regime abound in the highly structured atmosphere of the Sun. Their detailed measurements, in conjunction with a continuous refinement of their theories, can help yield atmospheric parameters that prove difficult to directly measure. The magnetic field strength often tops this list of desired parameters. However, the structuring transverse to magnetic structures is also important both for understanding both the fundamental properties of solar atmospheric structures and from the perspective of atmospheric heating. This talk will present some of our recent results on the theoretical understanding of both kink and sausage waves in coronal structures for which the physical parameters are transversely structured in a continuous manner. We will examine how this continuous transverse structuring influences the wave properties in general, and the periods and damping times in particular. Conversely, we will also address how the measurements of low-frequency waves and oscillations can help constrain the information on the transverse structuring.
Included in this talk will be: 1) standing sausage modes in flare loops and their seismological applications for inverting the measured quasi-periodic pulsations (QPPs) in solar flare lightcurves; 2) impulsively generated sausage wave trains in both coronal tubes and coronal slabs together with their applications for inferring the information on sub-resolution density structuring; 3) impulsively generated kink waves in solar coronal streamers and their applications for inferring the magnetic field strength in the extended solar corona.

MHD WAVE MODES OF TWISTED MAGNETIC FLUX TUBE: LONG WAVELENGTH APPROXIMATION

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The theoretical study of MHD wave propagation in the solar magnetic flux tubes is an important problem in modern solar physics. Recent space- and ground-base observations have shown that that twisted magnetic fields occur naturally, and indeed are omnipresent in the Sun's atmosphere. In the framework of ideal MHD, in this talk, we will discuss small amplitude incompressible wave modes with azimuthal wave number m=1 and m>1 of twisted magnetic flux tubes. Special attention will be given to the problem of finding the eigenvalues and eigenfunctions of modes with m=1 in the long wavelength limit. We will show that the dispersion relation for kink mode is completely unaffected by the radial profile of background internal magnetic twist. However, fluting modes are sensitive to the particular radial profile of magnetic twist chosen.

O. Cheremnykh, V. Fedun, A. Kryshtal, and G. Verth. Incompressible magnetohydrodynamic modes in the thin magnetically twisted flux tube. // A&A. – 2017. – DOI: https://doi.org/10.1051/0004-6361/201629863

MHD-KINETIC TRANSFORMATION OF ALFVÉNIC TURBULENCE AND FUTURE SPACE MISSIONS

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Recent studies have revealed that turbulence in magnetized plasmas is greatly affected by the Alfvén effect. The well-documented example is the solar-wind turbulence whose nature is essentially Alfvénic. Alfvénic turbulence is also widespread in many other space and astrophysical plasmas. Strong turbulence of MHD Alfvén waves (AWs) is anisotropic, generating preferentially larger perpendicular wavenumbers across the mean magnetic field [1]. Eventually, at ion kinetic scales, the turbulence of MHD AWs should transform into the turbulence of kinetic Alfvén waves (KAWs) [2]. Turbulence theory at ion scales is developed much less than in asymptotic MHD and kinetic ranges. In particular, there is still no consensus on the steep ion-scale spectra and preceding spectral break observed by satellites. We argue that these deficiencies of the theory are caused by the commonly accepted presumption that the turbulence is generated by the collisions between counter-propagating waves. Contrary to this, we found a new dynamical range at ion scales where the turbulence is generated by the collisions between waves propagating in the same direction along the mean magnetic field [2]. I will discuss new properties of this dynamical range and related energy release in solar and space plasmas, with a particular emphasis on the turbulence imbalance and non-adiabatic acceleration of particles. The problem with experimental verification of the theory is in the insufficient resolution of available spacecraft observations. Therefore, a significant improvement of the spacecraft payload is needed in future space missions oriented on turbulence and related phenomena. In this respect, we pin our hopes on the dedicated ESA mission THOR (Turbulence Heating ObserveR). I will describe the state of art of THOR and what we expect from it in view of recent theoretical controversies.

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SOLAR PLASMA RADIO EMISSION IN THE PRESENCE OF IMBALANCED TURBULENCE OF KINETIC-SCALE ALFVEN WAVES

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We study the influence of kinetic-scale Alfvenic turbulence on the generation of plasma radio emission in the solar coronal regions where the plasma/magnetic pressure ratio (plasma beta) is smaller than the electron/ion mass ratio m_e / m_i . The present study is motivated by the phenomenon of solar-type I radio storms associated with the strong magnetic field of active regions. The measured brightness temperature of the type I storms can be up to 10^{10} K for continuum emission and can exceed 10^{11} K for type I bursts. At present, there is no generally accepted theory explaining such high brightness temperatures and some other properties of the type I storms. We propose the model with the imbalanced turbulence of kinetic-scale Alfven waves producing an asymmetric quasilinear plateau on the upward half of the electron velocity distribution. The Landau damping of resonant Langmuir waves is suppressed and their amplitudes grow spontaneously above the thermal level. The estimated saturation level of Langmuir waves is high enough to generate observed type I radio emission at the fundamental plasma frequency. Harmonic emission does not appear in our model because the backward-propagating Langmuir waves undergo a strong Landau damping. Our model predicts 100% polarisation in the sense of the ordinary (o-) mode of type I emission.

ENERGY TRANSPORT BY INTERNAL GRAVITY WAVES IN MAGNETIZED SOLAR ATMOSPHERE

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Observations of the solar atmosphere show a wide variety of wave phenomena. Among them are the buoyancy-driven internal gravity waves (IGWs) - a phenomenon common in the terrestrial atmosphere and oceans. IGWs in the solar atmosphere are thought to be generated by overshooting convection, but are found to be suppressed at locations of magnetic flux as a result of mode conversion into other magneto-atmospheric waves. Here we present a study of the IGW spectrum emerging from realistic simulations of the solar convection. We compare a magnetic field free atmosphere with atmospheres of varying magnetic flux densities in order to investigate the effect of magnetic fields on IGWs. We find that, in the presence of predominantly vertical fields, IGWs are mainly reflected back to the lower atmosphere as a result of mode-coupling to slow magneto-acoustic waves. Energy transport by IGWs also show a dependence on magnetic flux density as a result of changes in the magneto-atmospheric conditions.

FLARE ENERGY RELEASE: INTERNAL CONFLICT, CONTRADICTION WITH HIGH RESOLUTION OBSERVATIONS, POSSIBLE SOLUTIONS

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All accepted paradigm of solar and stellar flares energy release based on 2 whales:
1. Source of energy is free energy of non-potential force free magnetic field in atmosphere above active region;
2. Process of ultrafast dissipation of magnetic fields is Reconnection in Thin Turbulent Current Sheet (RTTCS).
Progress in observational technics in last years provided ultra-high spatial resolution and in physics of turbulent plasma showed that real situation is much more complicated and standard approach is in contradiction both with observations and with problem of RTTCS stability. We present critical analysis of classic models of pre-flare energy accumulation and its dissipation during flare energy release from pioneer works Giovanely (1939, 1947) up to topological reconnection. We show that all accepted description of global force-free fields as source of future flare cannot be agreed with discovered in last time fine and ultra-fine current-magnetic structure included numerous arcs-threads with diameters up to 100 km with constant sequence from photosphere to corona. This magnetic skeleton of thin current magnetic threads with strong interaction between them is main source of reserved magnetic energy in solar atmosphere. Its dynamics will be controlled by percolation of magnetic stresses through network of current-magnetic threads with transition to flare state caused by critical value of global current.
We show that thin turbulent current sheet is absolutely unstable configuration both caused by splitting to numerous linear currents by dissipative modes like to tearing, and as sequence of suppress of plasma turbulence caused by anomalous heating of turbulent plasma. In result of these factors primary RTTCS will be disrupted in numerous turbulent and normal plasma domains like to resistors network. Current propagation through this network will have percolation character with all accompanied properties of percolated systems: self-organization with formation power spectrum of distribution of flares and micro-flares, and possibility of phase transition to flare energy release with huge increasing of energy release.

AN EXACT SOLUTION OF ENERGY PARTICLES MODULATION PROBLEM IN A STATIONARY COMPOSITE HELIOSPHERE MODEL

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A new theoretical approach for describing of physical stationary processes of energy particles propagation is proposed. The approach is based on an analytically iterative method [1] with the help of which it is possible to obtain approximate analytical solutions but with an acceptable accuracy for the problem of cosmic-ray (CR) modulation with a boundary spectrum (LIS). At the first, the approach was applied to find the distribution of CR in a simple model of the heliosphere wherein the diffusion coefficient and the solar wind (SW) speed are constants with LIS spectrum in the interstellar space. The solution obtained my means of the approach was compared with an analytical solution that may be obtained for this case and with numerical solution. There was shown a very good matching of the obtained solution with the compared solutions.
Finally, a classical problem of CR modulation in a stationary composite model of the heliosphere was considered. The model includes an environment that contains of two adjacent spherically symmetric regions. The first region is the heliosphere, which consists of the internal and the outer part. The internal part of the heliosphere is limited by a termination shock (TS), the radial SW speed is constant and supersonic, V in. Beyond TS, the SW speed jumps to a value V in /3 and spreads with deceleration in the outer part of the heliosphere, which is limited by the heliopause (HP). Such deceleration is presented in the form of a power law depending on r (the heliocentric distance) with index 'n'. The CR scattering for the internal and the outer of the heliosphere is due to different factors characterized by relevant diffusion coefficients that have dependence simultaneously on p (the momentum of the particle), v (the particle speed) and r. The second region of the environment is the interstellar medium, which is located beyond HP. Due to the absence of the SW speed inside the interstellar medium, the phase density of the particles is determined by only the diffusion process under the constant diffusion coefficient.
This problem has not purely analytical solution but the approximate analytical solution may be obtained by means of the proposed approach. The CR distribution for each region of the environment as for low-energy particles as well as high-energy particles was derived by the approach.

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MAGNETIC FIELDS AND THERMODYNAMICAL CONDITIONS AT PHOTOSPHERIC AND CHROMOSPHERIC LAYERS OF X17.2/4B SOLAR FLARE OF 28 OCTOBER 2003

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We present the magnetic field measurements and data of semi-empirical modeling for exclusively powerful solar flare of 28 October 2003 of X17.2/4B class which happened in active region NOAA 0486. According to data of the GOES detectors, this flare occupies the third position in the ranking of X ray on λ = 1-8 Å for the entire time since 1975. Spectral observations of the flare were carried out with the Echelle spectrograph of Horizontal Solar Telescope of Astronomical Observatory of Taras Shevchenko National University of Kyiv.
Twelve spectral lines were selected for analysis, including such well known lines as FeI 5247.052, 5250.212, 6301.515, 6302.507 Å, H_α, D3 HeI, etc. Two 'non-split' lines FeI 5434.527 and 5576.097 Å were studied too (their effective Lande factors are, in fact, –0.014 and –0.012, respectively, according to empirical determination in a laboratory).
Magnetic field strengths in the flare were measured by three methods: (1) by splitting of 'center of gravity' of I +/- V profiles; this method allows determine the effective magnetic field B_{eff} , which is, in fact, averaged strength inside all area of enter aperture of instrument, (2) by relative broadening of Stokes I profiles of FeI 5250.2 line versus 5247.1 line; this method allows estimate the 'turbulent' magnetic field B_{turb} on photospheric level of the flare and (3) using the PANDORA code which allows create the semi-empirical model of the flare.
We found that in brightes places of the flare the effective magnetic field B_{eff} was 0–200 G in the middle photosphere (FeI 6302.5 and 5250.2 lines), 600–1200 G in upper photosphere and temperature minimum zone (FeII 4923.9 and 5234.6 lines), and had S polarity. Turbulent magnetic field B_{turb} was found in range 800–1100 G along about 20 Mm of horizontal section of the flare in direction of entrance slit of the Echelle spectrograph.
In the FeI 5434.527 line, the weak but reliable splitting of emission peaks near its core was observed; its value is 10–25 mÅ. If this splitting to interpret as manifestation of the Zeeman effect, then corresponding magnetic field is 25–65 kG. Magnetic polarity of this 'superstrong' field should be N, i.e. opposite to polarity by other FeI lines with greater Lande factors.
Semi-empirical model of thermodynamical condition in the flare has two components: 'cold' and 'hot'. 'Hot' component has filling factor 10%; temperature T at this component is almost the same as at undisturbed atmosphere in range lgm from –3 to 1 (where m is in g/cm^2). However, for lgm < –3, a rapid grown of T is found, till about 24000K for lgm = – 4. Second 'cold' component has the temperature distribution with weaker deviation from undisturbed atmosphere.
A remarkable peculiarity of 'hot' component is very narrow and dense layer in range lgm = –3.6… –3.0 (Δh = 3-5 km, h = 1200 km) where density of plasma increases on about 4 order – till 10^{18} particles/cm^3. Most likely, our data reflect the existence of a current sheet indicating the magnetic reconnection of field lines in the flare. For existence of such sheet in the middle chromosphere, enough strong magnetic field ($\geq$ 300 G) is needed. Direct magnetic field measurements by H_α line shows that B_{eff} = 300±200 G, N polarity. It is necessary to note, that this is averaged field only, i.e. this is not local field. As to local magnetic fields in the flare, they can be much stronger, may be even ~10^4 G, as it follows from FeI 5434.527 line. The probable existence of such very strong fields in the flares presents a very important problem for modern solar physics.

INFLUENCE OF VARIABLE GRAVITY ACCELERATION ON RAYLEIGH-TAYLOR INSTABILITY

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Newtons gravity law states that gravity acceleration depends on the distance from the gravitating mass. This dependence is complex for self-gravitating fluid bodies, such as the Sun and other stars. The acceleration depends on the density distribution within a star. According to the standard model of the Sun, the density varies with depth by ten orders of magnitude, and the gravity acceleration changes by one order of magnitude. This variation may affect the development of various instabilities present in the solar plasma. In this work, we analyse numerically the effects of spatially-variable gravity acceleration on Rayleigh-Taylor instability and compare the flow structures for different dependences of the gravity acceleration on height in the model.

MANIFESTATION OF A NEW MAGNETIC FLUX EMERGENCE IN THE ACTIVE REGION NOAA 11024

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According modern concepts, many small-scale and large-scale dynamic phenomena observed on the Sun are related to the emergence of magnetic fluxes.
We present the results of studying the changes in physical conditions at different levels of the photosphere caused by the emergence of the new small-scale magnetic flux in the active region NOAA 11024. We analyzed spectropolarimetric data with high spatial and temporal resolution (about 3 seconds) obtained during 20 min with the French–Italian telescope THEMIS on Tenerife (Canary Islands) on July 4, 2009. We used the Stokes I and V measurements of the FeI 630.15 nm, 630.25 nm, 630.35 nm and TiI 630.38 nm lines that are formed over a wide range of photospheric heights. The region studied includes two pores of opposite polarity, active and quiet plages. Three Ellerman bombs (EBs) at different stages of their evolution were observed in it. The Stokes V profiles of the photospheric lines differed greatly in different sites of this region. From the analysis of the observed profiles, we have evidence for the presence of two small-scale mixed magnetic polarity patches in the region. One of them occupied part of the quiet plage area, and other located in the region of the active plage. They show strong temporal variations of the amplitude and the shape of the Stokes V parameter.
Eruptions appeared in these sites during the active region evolution. We investigated two Ellerman bombs that occurred in the region of one of the small-scale mixed magnetic polarity sites. During the observations, the brightness of EB-1 decreased, and brightness of EB-2 increased. The second EB appeared as a result of magnetic reconnections caused by the emergence of a new magnetic flux in this region, and then they developed as a physically connected pair. The peculiarities in the intensity variations of the Fraunhofer lines in the spectra taken at different stages of the EBs evolution were analyzed. The line-of-sight velocities of the photospheric material in the region of the EBs and in their vicinity were determined and analyzed, too. It was found that the profiles of the metal lines, obtained for different periods of development of the EBs, were asymmetric, with the asymmetry being more pronounced in weak lines. The largest changes of the profile shapes occurred in the FeI 630.25 nm line, the most magnetically sensitive among the lines studied in this work. It was found that when the central depth of the lines decreases, their half-width increases. In the spectrum of the EB central part, line central depth was less by 50%, and the line half-width was greater by 30%, compared to the line profile for the quiet photosphere. Upflows were observed at all levels of the photosphere in the region under consideration. The line-of-sight velocity in the EB regions changed from -1.3 to 0.1 km/s. It is noteworthy that, a noticeable decrease of the line-of-sight velocity magnitudes and the amplitude of their oscillations were observed at the location of the EBs. This probably indicates that small-scale downward movements were superimposed on the large-scale upward motion of the plasma new magnetic flux.
The temporal changes in the intensity of the Fraunhofer lines in the spectra of the AO region under investigation and the line-of-sight velocity of the photospheric matter in the Ellerman bomb regions and their vicinity indicate that in this region there was a pulse release of energy as a result of successive magnetic reconnections that were associated with the emergence of a new magnetic flux.

ANALYTICAL STUDY OF THE FRACTIONAL FOCUSED TRANSPORT EQUATION DESCRIBING ANOMALOUS DIFFUSION OF ENERGETIC PARTICLES

A. Attia
Ruhr University Bochum, Germany, *Ashraf.Attia@ruhr-uni-bochum.de*

The aim of this paper is to develop a fractional derivative model of energetic particles transport in magneto-static turbulence by deriving the fractional focused transport equation. Analytical solution of the space-time fractional focused transport equation is obtained by use of the Caputo and the Riesz fractional derivatives with the Laplace-Fourier technique. The solution is given in terms of Fox's H function.The predicted travelling pulse solutions are discussed in each case for different values of fractional order

SESSION 5:

Multi-scale plasma dynamic processes in the Sun-Earth system

Friday, 1 September

SOLAR COSMIC RAY KINETICS IN THE INTERPLANETARY MAGNETIC FIELD

Y. Fedorov[1], B. Shakhov[2]
Main Astronomical Observatory, National Academy of Sciences, Kyiv, Ukraine
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[2] *shakhov@mao.kiev.ua*

The solar cosmic propagation in the interplanetary medium is considered starting from the Boltzmann kinetic equation. It is shown that cosmic ray distribution function can be represented as the sum of distribution functions of unscattered particles and scattered ones. The energetic charged particle scattering by magnetic irregularities is described by Boltzmann collision integral. The solution of kinetic equation for the instantaneous isotropic particle source is reached, the spatial and temporal distributions of solar cosmic rays are analyzed.
The transition to diffusion approximation is carried out and results of this approximation are compared to the kinetic equation solution. The telegraph equation for particle density is derived and solved. Starting from the set of equations for spherical harmonics of the cosmic ray distribution function the new transport equation taking into account the second harmonic is carried out and solved. The solar cosmic ray transport under prolonged particle injection into interplanetary medium is also studied. The obtained results can be applied to the solar proton events analysis.

INFLUENCE OF SMALL-SCALE BERNSTEIN TURBULENCE ON LOW-FREQUENCY PLASMA WAVES IN PRE-FLARE CHROMOSPHERE OF THE SUN.

S. Gerasimenko[1], A. Kryshtal[2], A. Voitsekhovska[3], O. Cheremnykh[4]
Space Research Institute of NASU and NSAU, Kyiv, Ukraine
[1] *svetlaries@gmail.com*
[2] *alexandr.kryshtal@gmail.com*
[3] *anna.corvus@gmail.com*
[4] *oleg.cheremnykh@gmail.com*

We had considered the early stage of development of pre-flare process. The possibility of generation of second harmonic of oblique quasi-Bernstein modes in the «DH» (deca-hectogauss) range of amplitudes of magnetic fields in pre-flare chromosphere of active region has been demonstrated. The conditions for the occurrence and development of instability of second harmonic of Bernstein modes in this region have been obtained. These results confirm that generation of low-frequency plasma waves on the background of saturated Bernstein turbulence is possible in pre-flare plasma of the loop structures in solar active region. It has been shown that under conditions, typical for plasma of solar chromosphere, the solutions of dispersion relation for low-frequency waves can be of only two types – "family of kinetic Alfven waves" and "family of kinetic ion-acoustic waves". Appearance of turbulence in plasma does not mix these two families and has not significant influence on the shape of the waves.

A.N. Kryshtal, A.D. Voitsekhovska, S.V. Gerasimenko, O.K. Cheremnykh Effect of Small-Scale Bernstein Turbulence on Low-Frequency Plasma Waves in the Preflare Solar Chromosphere. Kinematics and Physics of Celestial Bodies, 2017, Vol. 33, No. 4, pp. 149–165.

ASYMPTOTIC GREENS FUNCTION FOR COSMIC RAY MODULATION PROBLEMS.

B. Shakhov
Main Astronomical Observatory of the NAS of Ukraine, Kyiv, *shakhov@mao.kiev.ua*

The evolution of the cosmic ray spectrum from an instantaneous, infinitely thin spherical source with a given energy is considered. At the boundary of the solar wind, the conditions for the equality of the cosmic ray concentration and the particle flux to zero are imposed. For these two cases Analytic expressions are obtained for the Green's function for small and long times, respectively. The possibility of accelerating cosmic rays is considered

ON NON-UNIVERSALITY OF SOLAR-TERRESTRIAL CONNECTIONS

L. Pustilnik
Tel Aviv University, Israel, *levpust2149@gmail.com*

Non-universality of the solar-terrestrial connection (STC) caused by complex and dynamical character of the dynamo process in the Sun from the one side and of the non-stability of the global atmospheric circulation in the Earth from the other side. These reasons lead from time to time to drastically change of the STC manifestations as whole. Partly it leads to change of the phase relations between different forms of the Earth environment responses (EER) on solar activity (SA). The dynamo mechanism, controlled SA, includes few basically elements (differential rotation, solar convection, toroidal and poloidal magnetic fields, global circulation and more). All this elements are connected one to another with direct and feedbacks causal-reason relations between them.

In result solar cycle has dynamically change in amplitude, in period and in phase behavior up to phenomena of strange attractor. This non-stationarity leads to different phase pattern of main manifestations of solar activity and its non-stability (sunspots number, flares frequency (with different phase patterns for different amplitudes), coronal holes, chromosphere emission and more). When this non-stability overlaps on non-stability of the global atmospheric and oceanic circulation, it leads to complex and non-stable response of the earth weather and climate on solar activity. We discuss this non-universal character of STC and its sequences for identification of solar variability in atmospheric, agriculture response and wheat price dynamics. We propose list of necessary conditions and possible scenarios of STC taking in account the non-universality of STC.

COMPARISON OF NARMAX, ARTIFICIAL NEURAL NETWORK, AND LOCALIZED LYAPUNOV EXPONENTS FOR GEOMAGNETIC INDICES PREDICTION

S. Ivanov
Space Research Institute of NASU and NSAU, Kyiv, Ukraine, *smivanov87@gmail.com*

This report focuses on the reconstruction of dynamic models of geomagnetic indices (DST, Kp, AE) using techniques of NARMAX, artificial neural network, and localized Lyapunov exponents. The Grassberger Procaccia algorithm is used to determine phase space dimension. The Farrar-Globera algorithm is used to solve multicollinearity problem. This report is also dedicated to the developed method of nonlinear discrete models identification. The developed method is based on maximizing uncertainty measure (for example, Shannon's entropy) of distances (norms) in a multidimensional phase space.

AN OPTIMIZATION APPROACH TO SPACE WEATHER PREDICTION: ROBUST NARMAX MODEL, LYAPUNOV EXPONENTS, PREDICTABILITY, AND REAL-TIME ALGORITHMS

V. Yatsenko
Space Research Institute of NASU and NSAU, Kyiv, Ukraine, *vyatsenko@gmail.com*

The NARMAX methodology is a powerful technique that is commonly used in the field of systems identification. One possible application of this technique the forecasting of geomagnetic indices, that can regarded as outputs of a complex dynamical system that incorporates both the magnetosphere and ionosphere. Results of NARMAX based approach to the dynamics of Kp and Dst indices are reviewed. It is shown how the transform of the identified mathematical model of geomagnetic indices from time domain to the frequency domain can be used to determine the the properties of the physical processes involved. New nondifferentiable optimization approach to NARMAX identification problem is considered.

ACTIVITY OF PROXIMA CEN.

Y. Pavlenko[1], A. Suarez Mascaren[2], R. Recolo[3], N. Lodieu[4], V. Bejar[5]
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[2] Observatoire Astronomique de l'Universite de Geneve, Switzerland, *AlejaAlejandro.SuarezMascareno@unige.ch*
[3] IAC, Spain, *rrl@iac.es*
[4] IAC, Spain, *nlodieu@iac.es*
[5] IAC, Spain, *vbejar@iac.es*

We carried out the analysis of emission and absorption spectra using high-resolution optical observation data obtained on HARPS. We identify a lot emission lines of the neutral metals in a series of 147 high-resolution optical spectra of the star at different levels of activity and compare them with the synthetic spectra. Hydrogen emission lines of different series dominate in the emission spectrum. He I lines of high excitation energies are strong enough, too. It looks like emission lines of Proxima form in the parts of atmosphere of different temperatures. He I and H I lines show strong temporal variability in the different time scales. Furthermore, we detected the component of comparatively hot stellar wind moving outwards with high velocity.

AGW/TID AND SPORADIC IONOSPHERIC STRUCTURES OVER THE ANTARCTIC PENINSULA

A. Zalizovski[1], Y. Yampolski[2], E. Mishin[3], A. Koloskov[4], S. Kashcheyev[5], I. Pikulik[6], A. Sopin[7], E. Zanimonsky[8], V. Lisachenko[9], V.V. Paznukhov[10]

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[5] Institute of Radio Astronomy of NAS of Ukraine, *kasceev@rian.kharkov.ua*
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[7] Institute of Radio Astronomy of NAS of Ukraine, *sopin@rian.kharkov.ua*
[8] Institute of Radio Astronomy of NAS of Ukraine, *zanimonskiy@rian.kharkov.ua*
[9] Institute of Radio Astronomy of NAS of Ukraine, *lisachen@rian.kharkov.ua*
[10] Institute for Scientific Research, Boston College, USA, *vadym.paznukhov@bc.edu*

The paper presents the results of diagnostics of travelling ionospheric disturbances (TID) over the Antarctic Peninsula obtained by using two different techniques. The first method is based on multi-positional GNSS TEC measurements, and the second one is bistatic coherent ionospheric HF radio sounding. Quasi-periodic variations associated with the propagation of TID were registered simultaneously in both types of the data. The significant daily variations of the TID periods were found by using the data of HF Doppler ionospheric sounding on the radio path between Akademik Vernadsky and Palmer (USA) stations. The diurnal and seasonal variations of the TID propagation directions were estimated by the data of network of GNSS stations located at the region of Antarctic Peninsula. Based on the results of processing, it can be concluded that the AGW/TID over the Antarctic Peninsula are usually travelling against the prevailing direction of thermospheric winds.

The sporadic E layers (Es) and spread-F over the Antarctic Peninsula and their dependence on weather and geomagnetic conditions are studied as well. As a result of analysis of more than 20-year experimental databases accumulated at Akademik Vernadsky station it was found that both Es and spread-F dependent on the tropospheric weather mostly at the winter time. The almost linear dependence of spread-F appearance on the geomagnetic disturbances was found. The dependence of Es occurrence frequency on the local K-index demonstrates the non-linear character with the maximum at K = 2. At the winter time the maximum of Es occurrence shifts to local K = 0…1. The experimental results can be explained by propagation of atmospheric gravity waves (AGW) in the Earth's ionosphere. The seasonal variations in the effects could be associated with changes of intensities of troposheric and auroral sources of AGW and vertical profiles of temperature and horizontal winds.

This study has been carried out with the support of EOARD-STCU partner project P667, and NSF project #1341557

Index of Authors

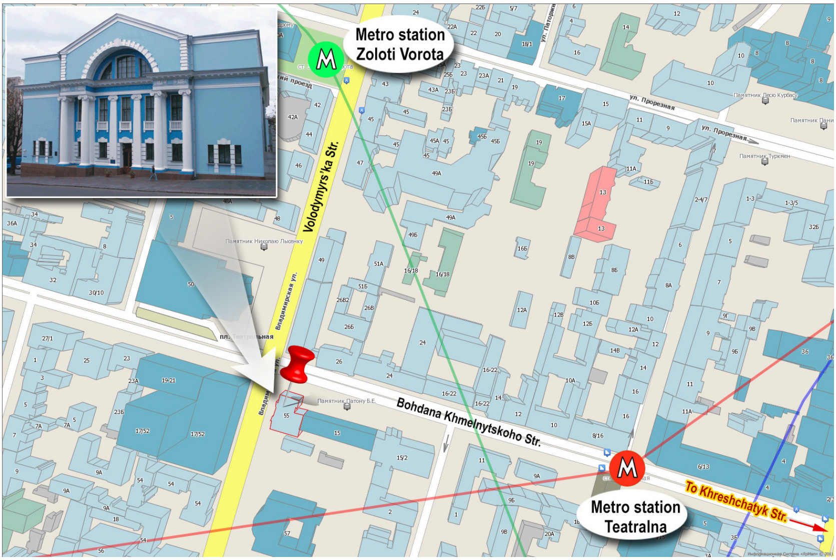
INFORMATION

Important telephone numbers
Ambulance: 103
Police: 102
Fire Department: 101

Usually emergency services staff is able to communicate in English. But in opposite case, if the need arises, ask someone fluent in Ukrainian/Russian to help explain the nature of emergency to the services involved.

Meeting venue

The conference will take place in Ukraine's National Academy of Sciences Section Hall. The National Academy of Sciences is located in the picturesque part of the old Kiev City Centre. Address: Volodymyrska Street 55 (marked as a red pin on the map below).



Money/shopping

Ukrainian local currency is Hryvnya — pronounced as grivna — (UAH).
Approximate exchange rates:
1 GBP = 32.6 UAH
1 EUR = 28.4 UAH
1 USD = 26.8 UAH

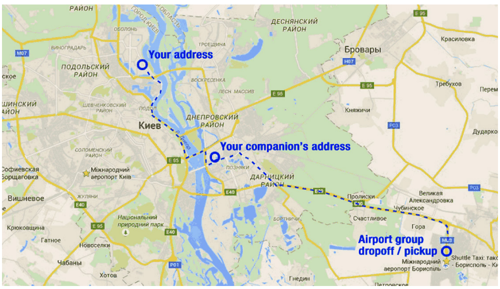
Travel by taxi from/to Boryspil Airport

There are many taxi services in Airport; we suggest also:

Shuttle Taxi is a first Ukrainian Shared Transfer Service working on **Kyiv – Boryspil' Int'l Airport – Kyiv** routes.

http://shuttle-taxi.com.ua/en/

As you place an order, we pick up passengers from two or three (maximum) addresses on our way, *Here is example of our typical route. It takes from 40 to 80 minutes to reach final destination point.*



We offer flat rates (any address):

1 person = 119 UAH (apprx. 4.5 EUR only)*

2 persons (one address) = 139 UAH (apprx. 5 EUR only)*

3 persons (one address) = 159 UAH (apprx. 5.5 EUR only)*

4-6 persons (one address) = 419 UAH (apprx. 15 EUR only)**

7-9 persons (one address) = 479-579 UAH (apprx. 17-21 EUR only)**

* if there is another passenger in your shuttle.

** mini-bus Mercedes Vito, Renault Trafic – like class.

How to use:

Place an order (date, time, address etc.)

We determine if we can pick another passengers up in your shuttle

We contact you in several hours before picking you up and tell you final price and time*

** in there are no another passengers, we can send you private taxi; you may know the price of private taxi from our operators via phone or chat on website (in the right corner)*

NB: the typical price for personal taxi from airport to the center of Kyiv is about 10 EUR;

Our Pluses:

We work 24x7.

We pay attention on you landing. You tell us your flight number, we watch it online.

No extra fees on night, on preliminary orders, on card payment etc.

You may pay by card (Visa/Mastercard).

We call on foreign (non-Ukrainian) phone numbers.

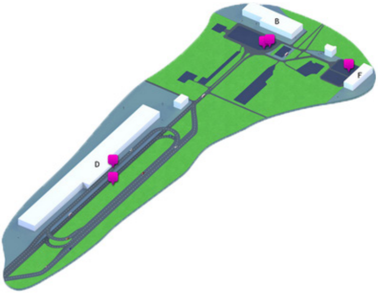
You may contact us via Skype, Viber, WhatsApp.

We speak English.

Travel by bus from/to Boryspil Airport

Boryspil Airport has 3 terminals in operation: B, D, and F. Most international flights arrive in the terminals D or F, whereas terminal B is used for domestic flights.

The simplest way to get to the city centre from Boryspil International Airport is the ’**Sky Bus’**, which operates a regular bus service between the airport and Central Railway station. Buses depart every 15 minutes during rush hour, or every 45 minutes in the middle of the night, 24 hours per day, and the cost is 40 UAH (see details here **http://skybus.kiev.ua/en/**).



Tickets are bought directly from the driver or from ’Kiyavia’ booking-offices located in each terminal. The journey to the city center takes 40 to 70 minutes. The buses stop in the front of every terminal. Buses terminate at the southern side of the railway station. To get to the metro (’Vokzalna station’) from the bus stop, enter the railway terminal, follow the bridge over the railway, leave the building, and turn left.

Kyiv International Airport ’Zhuliany’
http://www.airport.kiev.ua/en/

is located 8 kilometers south-west of the city center. It is mostly served by budget airlines. Wizzair is the major airline operating to this airport. From ’Zhuliany’ you can use Kiev’s public transport to reach your accommodation or the train station. There are two terminals — they are around 1 kilometer away from each other. They’re connected by trolleybus no. 22 that takes you further downtown.

Travel in Kyiv by taxi

Taxis in Kyiv are relatively cheap when compared to Europe. However, taxi drivers tend to make you pay more than the normal price. Always ask for the full price before you get into the taxi to avoid disappointment and unnecessary negotiation after you have already travelled. Taxi rides are paid by cash only, and it is unlikely you will get a receipt. The following is an approximate and is given as a guide for what you expect to pay:
Please use the following phone numbers to call a taxi:

+ 38 050 352 53 66 (Panda Taxi)
+ 38 044 455 95 95 (Absolut Taxi)
+ 38 044 401 07 07 (Econom Taxi)

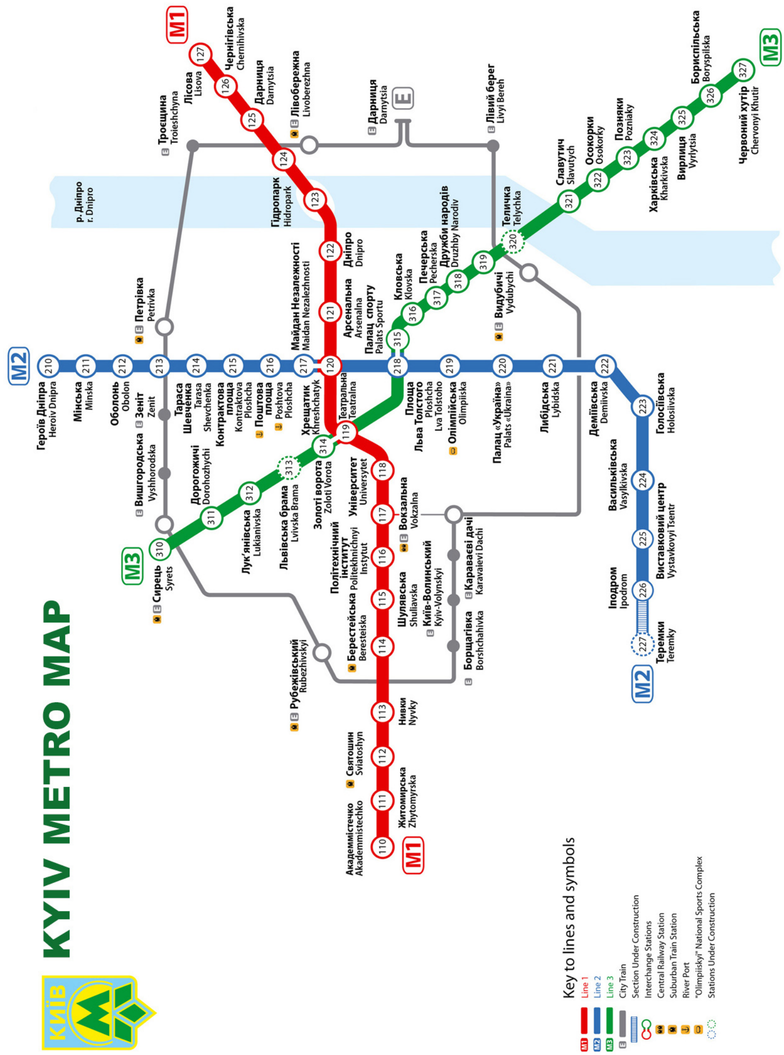
Don't expect the services to speak English. It would be best to contact the conference organisers or the hotel personnel to book a taxi and arrange your trip for you.

Travel in Kyiv by metro

1. Finding the metro.
To find the entrance to the metro, look for the big green **M**.
The **M** marks the stairs that lead underground, but be aware that there is often a busy collection of kiosks, tunnels, cash machines (ATMs) and grandmas selling stuff like bread or knickers before you get to the metro itself.

2. Accessing the metro.
Enter > buy a ticket > get through the gates.
Your first big challenge will be the swinging doors that guard the metro. These glass and metal doors swing (fast) in both directions, they are heavy enough to kill a bear and unless you're old, it is possible that the person in front of you will hold the door open for you. So, just be ready and be careful to catch the thing as it swings back in your face. If you're clever, you can pass the door as the wind coming from the station blows it open, or as it swings open after the last person entered. However, both of these are advanced metro skills and shouldn't be tried during your short visit.

3. Buying a 'ticket'.
The fare in the metro in Kiev is 5 hryvnia. Now in Kiev there is a transition from the old form of payment for travel to the metro — plastic tokens — to new forms, paper one-time coupons with QR-code and electronic cards for several trips. You can purchase them (as well as old tokens which are actual in August — September) at metro stations. Electronic turnstiles can also on several stations accept payment by credit and bank cards. Vending machines for ticket sales and account recharge on reusable cards are located in the lobby of the stations, as well as ordinary cash desks. Instructions on automatic machines are usually duplicated in English. At each station there is at least one English-speaking employee or policeman who can help you to buy a ticket or choose the station you need. The names of the stations in the metro train are announced in Ukrainian and English.


Київ
KYIV METRO MAP
M1
110 Академмістечко Akademmistechko
111 Житомирська Zhytomyrska
112 Святошин Sviatoshyn
113 Нивки Nyvky
114 Берестейська Beresteiska
115 Шулявська Shuliavska
116 Політехнічний інститут Politekhnichnyi Instytut
117 Вокзальна Vokzalna
118 Університет Universytet
119 Театральна Teatralna
120 Хрещатик Khreshchatyk
121 Арсенальна Arsenalna
122 Дніпро Dnipro
123 Гідропарк Hidropark
124 Лівобережна Livoberezhna
125 Дарниця Darnytsia
126 Чернігівська Chernihivska
127 Лісова Lisova
M2
210 Героїв Дніпра Heroiv Dnipra
211 Мінська Minska
212 Оболонь Obolon
213 Петрівка Petrivka
Зеніт Zenit
214 Тараса Шевченка Tarasa Shevchenka
215 Контрактова площа Kontraktova Ploshcha
216 Поштова площа Poshtova Ploshcha
217 Майдан Незалежності Maidan Nezalezhnosti
218 Площа Льва Толстого Ploshcha Lva Tolstoho
219 Олімпійська Olimpiiska
220 Палац «Україна» Palats «Ukraina»
221 Либідська Lybidska
222 Деміївська Demiivska
223 Голосіївська Holosiivska
224 Васильківська Vasylkivska
225 Виставковий центр Vystavkovyi Tsentr
226 Іподром Ipodrom
227 Теремки Teremky
M3
310 Сирець Syrets
311 Дорогожичі Dorohozhychi
312 Лук'янівська Lukianivska
313 Львівська брама Lvivska Brama
314 Золоті ворота Zoloti Vorota
315 Палац спорту Palats Sportu
316 Кловська Klovska
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Троєщина Troieshchyna
Дарниця Darnytsia
E
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Вишгородська Vyshhorodska
Рубежівський Rubezhivskyi
Київ-Волинський Kyiv-Volynskyi
Караваєві дачі Karavaievi Dachi
Борщагівка Borshchahivka
р. Дніпро r. Dnipro
Key to lines and symbols
Line 1
Line 2
Line 3
City Train
Section Under Construction
Interchange Stations
Central Railway Station
Suburban Train Station
River Port
"Olimpiiskyi" National Sports Complex
Stations Under Construction

10 Tourist attractions in central part of Kyiv

There are plenty of them! To obtain more information on tourist attractions in Kyiv please ask the hotel personnel or the conference organisers.

1. Khreshchatyk and Independence Square.

Measuring around 1.5 km in length, Khreshchatyk is Kiev's most famous and well-trodden street. During World War II the retreating Soviet Army mined most of it as a welcoming present or the advancing Nazis. It was gratefully accepted, resulting in complete destruction of most of the existing buildings. When the war ended, the street was rebuilt with imposing Stalinist style buildings that still dominate the area today.

Khreshchatyk really comes to life at weekends and on public holidays, when the busy road is closed to traffic and becomes the home of street performers and musicians.

The focal point of Khreshchatyk and Kiev's most popular meeting spot is Independence Square. Dominating the area is the Monument of Independence, a huge pillar erected in 2001 to celebrate 10 years of Ukrainian separation from Russia. Ironically, just a short distance away, the Friendship of the Nations monument celebrates the 1654 integration of the two countries.

Since 2004 Independence Square is more known in the Woirld as **Maidan** — place of Orange Revolution. 9 years later, at November, 2013, the dramatic events of new Ukrainian revolution defending the European choice of Ukrainians also occurred here.

2. Kyivo-Pecherska Lavra.

Tourists and Orthodox pilgrims alike flock to the Lavra. Set on 28 hectares of grassy hills above the Dnipro River, the monastery's cluster of gold-domed churches is a feast for the eyes, the hoard of Scythian gold rivals that of the Hermitage in St Petersburg, and the underground labyrinths lined with mummified monks are exotic and intriguing. That's from a tourist's perspective, but for pilgrims this is simply the holiest ground in three East Slavic countries – Ukraine, Russia and Belarus.

A lavra is a senior monastery, while pecherska means 'of the caves'. The Greek St Antony founded this lavra in 1051, after Orthodoxy was adopted as Kyivan Rus' official religion. He and his follower Feodosy progressively dug out a series of catacombs, where they and other reclusive monks worshipped, studied and lived. When they died their bodies were naturally preserved, without embalming, by the caves' cool temperature and dry atmosphere. The mummies survive even today, confirmation for believers that these were true holy men.

The monastery prospered above ground as well. The Dormition Cathedral was built from 1073 to 1089 as Kyiv's second great Byzantine-inspired church, and the monastery became Kyivan Rus'

As this is the city's single most fascinating and extensive tourist site, you will need at least half a day to get a decent introduction. Try to avoid the Lavra on weekends, when it gets extremely busy.

3. St Sophia's Cathedral.

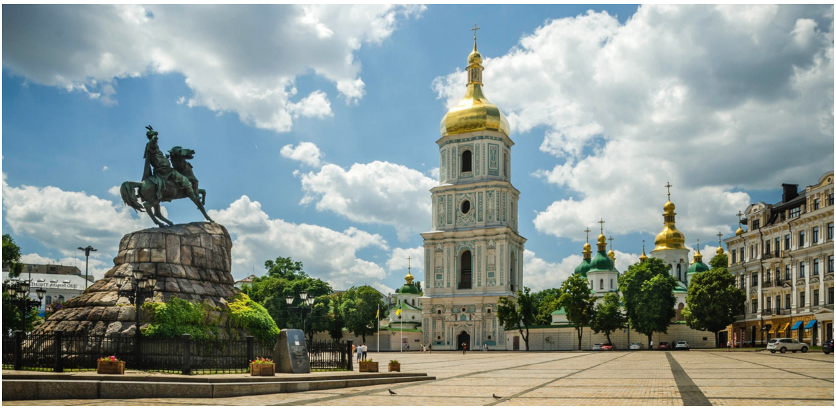
The interior is the most astounding aspect of Kyiv's oldest standing church. Many of the mosaics and frescoes are original, dating back to 1017–31, when the cathedral was built to celebrate Prince Yaroslav's victory in protecting Kyiv from the Pechenegs (tribal raiders). While equally attractive, the building's gold domes and 76m-tall wedding-cake bell tower are 18th-century baroque additions.

Named after the great Hagia Sofia (Holy Wisdom) Temple (currently a mosque) in Istanbul, St Sophia's Byzantine architecture announced the new religious and political authority of Kyiv. It was a centre of learning and culture, housing the first school and library in Kyivan Rus. Adjacent to the Royal Palace, it was also where coronations and other royal ceremonies were staged, treaties signed and foreign dignitaries received. Prince Yaroslav himself is buried here – or at least everyone thought so until a few years ago. His remains are believed to have been smuggled into the US by a collaborationist priest, who left Kyiv with the retreating German army during WWII. The Ukrainian government is engaged in negotiations about their return.

Each mosaic and fresco had its allotted position according to Byzantine decorative schemes, turning the church into a giant 3D symbol of the Orthodox world order. There are explanations in English of individual mosaics, but the one that immediately strikes you is the 6m-high Virgin Orans dominating the central apse. The Virgin Orans is a peculiarly Orthodox concept of the Virgin as a symbol of the earthly church interceding for the salvation of humanity. Having survived this long, this particular Orans is now thought indestructible by Orthodox believers. (Unesco was slightly less certain, adding the cathedral to its protective World Heritage list in 1990.)

Less obvious, but worth seeking out, are fragments in the central nave and the north stairwell of two group portraits of Yaroslav and family. The prince's tomb is found on the ground floor, in the far left corner from the main entrance.

In front of the cathedral complex on pl Sofiyska is a statue of Cossack hero Bohdan Khmelnytsky. Just before the bell tower lies the ornate tomb of Kyiv Patriarch Volodymyr Romanyuk. Religious disputes prevented him from being buried within the complex.



4. Andriyivsky Uzviz.

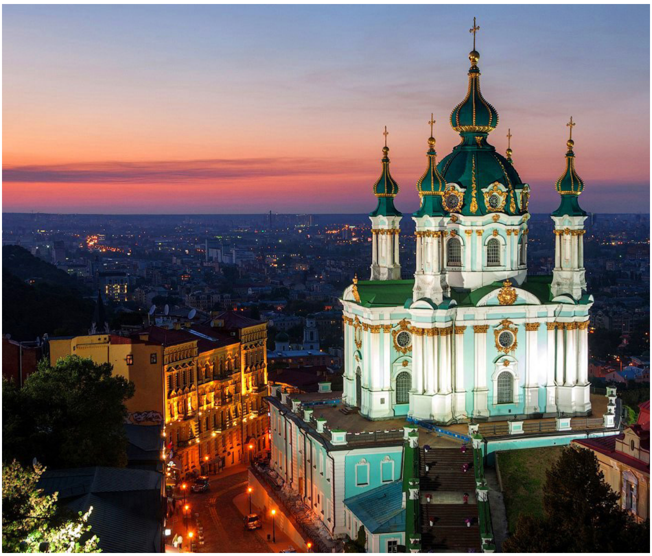
According to legend, a man walked up the hill here, erected a cross and prophesied: 'A great city will stand on this spot'. That man was the Apostle Andrew, hence the name of Kyiv's quaintest thoroughfare, a steep cobbled street that winds its way up from Kontraktova pl to vul Volodymyrska, with a vaguely Monparnasse feel. Its highlight is the stunning gold and blue St Andrew's Church, a five-domed, cross-shaped baroque masterpiece that celebrates the apostle legend.

The church was built in 1754 by Italian architect Bartolomeo Rastrelli, who also designed the Winter Palace in St Petersburg.

There are other diversions galore along Andriyivsky uzviz, including a few wonderful cafes, restaurants, galleries, craft shops and museums. At the foot of the uzviz, the individual histories of the Descent's buildings are laid out in the Museum of One Street. The sheer jumble-sale eclecticism of the collection – showcasing the lives of dressmakers, soldiers, a rabbi, a Syrian-born orientalist and more – exudes bags of charm.

A little way up on the left, the early home of the much-loved author of The Master and Margarita has become the strange and memorable Bulgakov Museum, designed as an alternative universe populated by the author's memories and characters. Mikhail Bulgakov lived here between 1906 and 1919, long before writing the novel, but this building was the model for the Turbin family home in The White Guard, his first full-length novel. A restaurant just down the street has a bolder reference to The Master and Margarita, with the figure of a smug, fat black cat – the devil's mischievous sidekick, Behemoth – adorning its facade.

The huge Stalinist building behind the site is the National Museum of Ukrainian History. It has exhibits of archaeological and recent historical interest, including books and coins. To the left of the museum begins Peyzazhna Alley, an uncrowded promenade with excellent views of Podil. It skirts the ravine and abuts vul Velyka Zhytomyrska.



5. Peyzazhna alleya.

Starting at the top of Andriyivsky uzviz by the National Museum of Ukrainian History, the alley skirts around a large ravine offering great views of the city. It's always full of people and there is a cluster of modern urban art in its middle section.

This is a great place to visit for adults and kids alike. Lots of fun sculptures and artistic objects scattered over a hilly area where you will have great views over the city. The park includes sculptures and installations created by Ukrainian artists. There are also the unique garden benches designed from the sketches of well-known Ukrainian fashion designers. Do not forget your camera and wear a good pair of walking shoes.

6. Bohdan & Varvara Khanenko Museum of Arts.

Kyiv's most impressive collection of European art boasts Bosch, Velázquez and Rubens among the many masters represented, but they are only part of the attraction. The house, with its frescoed ceilings and intricately carved woodwork, alone is worth the price of admission. All the better that it's packed with priceless antique furniture, ancient Greek sculptures, porcelain ceramics and dazzling paintings, such as a version of Hieronymus Bosch's Temptation of St Anthony. The museum's climax is on the top floor: four rare religious icons from the 6th and 7th centuries. Even if icons aren't your thing, it's hard not to be moved by these primitive Byzantine treasures. And we've only described the 'Western' wing. The 'Eastern' wing has Buddhist, Chinese and Islamic art.

7. Water Museum.

Inside a historical water pump, this Danish-funded museum is a fun place, especially for children. On the obligatory tour, you're taken on a walk through a rainwater collector, allowed to sit on a giant toilet or stand inside a bubble, and introduced to a yellow fish called Vasily.

Well organized displays and excellent information in an interesting setting in an old water tower. The hands-on part of the tour is great fun; they should develop more hands-on exhibits. The staff was very helpful and friendly. If you want atour in English rather than Ukrainian just tell them.

8. House of Chimeras.

Hard to say which other national president has a bunch of otherworldish creatures peering into his window, but the Ukrainian one does for his office is face-to-face with Kyiv's weirdest edifice. The 'chimeras', which cover every patch of architect Wladislaw Horodecki's creation, are in fact depictions of his exotic hunting trophies – elephants, rhinos, crocodiles, lions and whatever you name. He kept many prototypes inside – in the stuffed form.

The Art Nouveau house, which he built for himself in 1903, is placed on a high cliff so it appears as a six-storey structure on one side and three-storey on the other. The 'chimeras' are here not only to decorate, but also to advertise the revolutionary building material – concrete, of which Horodecki was a huge fan. Many locals say that the house is best admired at night, when spooky creatures seem ready to come alive and jump down from the roof.


9. Zoloti Vorota (Golden Gate).

Part of Kyiv's fortifications during the rule of Yaroslav the Wise, the famous Zoloti Vorota sounds much better than it looks, but the summer patio around the fountain out the front is a great place to have a drink. Erected in 1037 and modelled on Constantinople's Golden Gate, this was the main entrance into the ancient city, with ramparts stretching out from both sides. However, the gate was largely destroyed in the 1240 Mongol sacking of Kyiv, and what you see today is a 1982 reconstruction that encloses whatever remains of the original. The statue to the side is of Yaroslav, although people call it 'monument to the Kyiv cake' – you'll understand why when you see it.


10. Fomin Botanical Gardens.

The A.V. Fomin Botanical Garden is one of the oldest botanical gardens in Ukraine, located in Kyiv. In 1839 the Kyiv Taras Shevchenko University opened its own botanical garden. The botanical garden is 22.5 hectares (0.225 km^2), with 8,000 plant species, including 143 recorded in the Ukraine's Red Book of Rare Species. The Garden is famous for its exotic plants: it has the biggest collection of succulents among the countries of the former Soviet Union. The greenhouse, which was built for the largest and the oldest palm trees in Northern Eurasia, is among the highest in the world. In 1935 the garden was named after the academician and botanist Aleksandr Vasiljevich Fomin, who directed the garden for years. The vestibule of the Kiev Metro station Universytet, is located on the northern edge of the garden, which was opened in 1960.