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International solar conference in Baku 2015

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A review of the materials of the International Conference "The Variability of the Sun and Sun-like Stars: from Asteroseismology to Space Weather" is presented. The conference was held in Baku in July 2015.

Keywords: Sun, asteroseismology, solar magnetism, solar neutrino, solar flares, corona, solar wind, solar activity, sun-like stars

The International Conference "Variability of the Sun and Sun-like Stars: from Asteroseismology to Space Weather" was held in Baku, Azerbaijan on 6–8 July 2015. The conference was devoted to the 70-years anniversary of the Azerbaijan National Academy of Sciences and the 60-years jubilee of the establishment of the Shamakhy Astrophysical Observatory. The conference took place in Baku (6–7 July), but one conference session (8 July) was held at the Shamakhy Astrophysical Observatory (about 145 km from Baku). The aims of the conference were to highlight all aspects of modern solar physics research, including observation and theory that span from the interior of the Sun out into the wider heliosphere, particularly solar-terrestrial physics and space weather effects, as well as the problem of sun-like stars. The conference provided a broad, yet stimulating, environment for domestic and international scientists to share the findings of their research in solar and solar-terrestrial physics. The conference was financially and organizationally supported by the Science Development Foundation under the President of the Republic Azerbaijan. Conference co-organizers are Azerbaijan National Academy of Sciences, Shamakhy Astrophysical Observatory, Pushkov Institute of Terrestrial Magnetism, Ionosphere and Radio Wave Propagation of the Russian Academy of Sciences (IZMIRAN) and Euro-Asian Astronomical Society (EAAS). The conference comprised invited reviews and contributed talks on individual research within the theme of the conference. The main topics of the conference were:

- problems of asteroseismology;
- solar neutrino problem and its solution scenarios;
- solar magnetism dynamo theory;
- solar flares observation and theoretical aspects;
- the problem of solar corona heating;

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- the theory of the coronal mass ejection;
- observational aspects of the solar wind, solar wind theory, the interaction of the solar wind and the magnetosphere of the Earth;
- space and ground-based observations of the Sun;
- physics of solar-terrestrial relations;
- space weather effects;
- heliobiological studies;
- solar activity and changes in climate of the Earth;
- sun-like variable stars and their evolution.

The scientific program of the conference was opened by Professor J. Christensen-Dalsgaard (Aarhus University, Denmark) with a review of stellar seismology, which includes a significant part of helioseismology, that has provided very detailed information about the interior structure and dynamics of the Sun, highlighting the remaining issues in our understanding of the solar interior. In the last decade extensive observations of stellar oscillations, in particular from space photometry have provided very detailed information about the global and internal properties of stars. These results allow a better understanding of our Sun and solar activity. The history of research on helioseismology, and also plans for the future of the Ulugh Beg Astronomical Institute (Uzbekistan), was covered by the Director Sh. Ehgamberdiev in his report.

The helioseismology project aimed to study the deep interior of the Sun using Doppler spectral line shift measurements integrated over the whole solar disk. In addition, from 1996 to 2002 the Ulugh Beg Astronomical Institute was involved in observations for TON (The Taiwan Oscillation Network) project, which aimed to carry out helioseismic studies of the subsurface structure of the Sun and its dynamics. The most important scientific result obtained using helioseismology the TON experimental data was the first estimation of sunspot depth.

Professor A. Kosovichev (New Jersey Institute of Technology, USA) presented the past achievements of helioseismology and its prospects in obtaining information on physical processes which control development and magnetic activity of the Sun. In recent years, helioseismology has made substantial progress towards the understanding of the physics of solar oscillation and physical processes inside the Sun, thanks to substantial observational, theoretical and modeling efforts. In addition to global seismology of the Sun based on measurements of global oscillation modes, a new field of local helioseismology, which studies oscillation travel times and local frequency shifts, has been developed. It is capable of providing 2D images of subsurface structures and flows, and has provided critical information for modelling the solar activity cycles, understanding of sunspot structure and dynamics, prediction of emerging active regions and solar variability.

The study of magnetohydrodynamic (MHD) waves and oscillations in the corona of the Sun is one of the most rapidly developing research topics. In his talk, Professor V. Nakaryakov (University of Warwick, UK) described how these phenomena are confidently resolved in time and in space with modern high-cadence imaging instruments as periodic variation of EUV, soft X-ray and microwave emission, and also with spectral instruments as periodic Doppler shifts or broadenings. The detected wave motion comprise several different classes including standing and propagating kink oscillations, standing sausage oscillations, standing longitudinal oscillations, and propagating fast and slow compressive waves. These observational findings are found

to be well-consistent with the result of advanced modelling in terms of MHD theory. The excellent agreement of observational and theoretical result provided us with the basis for the implementation of a novel technique for the remote diagnostics of solar plasmas, MHD seismology. This approach has provided us with invaluable information about the absolute value of coronal magnetic field, fine structure, adiabatic index, and density scale height.

The wave instabilities in collisionless anisotropic temperature plasma in an anisotropic MHD model based on the 16-moment approximation are analyzed in talk of Professor N. Dzhalilov (Shamakhy Astrophysical observatory, ANAS, Azerbaijan). The results are found to agree well with those obtained in the low-frequency limit of the kinetic model. It is shown that accounting for heat leads to an asymmetry in the phase velocities of the wave modes with respect to the heat flux direction and also to a strong interaction between the modes; especially between the backward ones (those that propagate in a direction opposite to that of the heat flux). The resonant interaction of three backward modes – fast acoustic, fast magnetosonic, and slow acoustic – under the conditions for the onset of the classical fire hose instability triggers a new type of instability the growth rate of which is faster than the maximum growth rate of the conventional fire hose instability. The result proves that, in contrast to the familiar CGL (Chew–Goldberg–Low) approximate model, the anisotropic MHD approach provides a correct description of the large-scale dynamics of collisionless anisotropic plasmas, such as solar corona, solar wind, and ionospheric and magnetospheric plasmas. In the talk it was shown that: (i) aperiodic mirror instabilities of slow MHD waves can develop under solar coronal conditions for weak magnetic fields ($B < 1$ G) and periodic ion-acoustic instabilities can develop for strong magnetic fields ($B > 10$ G); (ii) the instability growth rates and estimated the temporal and spatial scales of development and decay of the periodic instability; (iii) the instabilities under consideration can play a prominent role in the energy balance of the corona and may be considered as a large-scale energy source of the wave coronal heating mechanism.

The talk of I. Kitashvili (NASA Ames Research Center, USA) about modern high-resolution observation from ground and space telescopes reveals a complicated dynamics of turbulent magnetoconvection and its effects in solar and stellar atmosphere and corona, showing intense interactions across different temporal and spatial scales. Interpretation of the observed complex phenomena and understanding of their origins is impossible without advanced numerical models. The rapid growth of computational capabilities has made possible 3D radiative MHD numerical simulations that reproduce condition in the solar and stellar interiors and atmospheres with a high degree of realism. Such simulations allow us to determine physical processes hidden from direct observations. They also provide synthetic data for calibration of observational data and for developing and testing ideas for improved diagnostics, in particularly, for modelling multi-scale turbulent magnetoconvection, MHD waves, magnetic self-organization phenomena in photosphere, their dynamical interaction with chromospheric layers, and modelling of spectro-polarimetric observations for different instruments.

The importance of observation and interpretation of solar neutrino experiments in the understanding of the physical processes inside the Sun was shown in the report of Professor V. Gavrin (Baksan Neutrino Observatory, Institute for Nuclear Research, RAS, Russia). The solution of the "solar neutrino problem" – the observed num-

ber of solar neutrino in the first experiments turned out to be much smaller than the predicted values based on Standard Solar Models – and took about 30 years of experimental research that led to the discovery of neutrino oscillation. Today the neutrino deficit observed in all the solar neutrino experiments is explained in terms of neutrino oscillation including the MSW (Mikheyev–Smirnov–Wolfenstein) effect. At the present time with acceptable accuracy we know the value of almost all neutrino fluxes from the pp-chain. The missing component is the flux of neutrino from the CNO (carbon–nitrogen–oxygen) cycle, which is of fundamental astrophysical importance and, in addition, in is highly sensitive to solar abundances. Today experimental data provide only an upper limit of the contribution of the CNO cycle to the total solar energy generation. Recent results of research on more robust determination of solar metal abundances have identified a discrepancy between helioseismology and calculations of Standard Solar Models, which was called "solar abundance problem". The experiments on measurements of neutrino fluxes from CNO cycle which could shed light on this intriguing problem are strongly demanded.

The characteristics of the solar cyclicity, using only reliable series of relative sunspot number in the last 160 years have been examined in his talk V. Ishkov (IZMIRAN, Russia). The scenario showed of the regular changes of magnetic field in the solar convection zone generation regime in the transition period from the epoch of "increased" (<8–10 and 18–22 solar cycles) to the epoch of "lowered" (12–16, >24) solar activity (SA) and vice versa – from the epoch of the "lowered" to "increased" solar activity. These epochs significantly differ from each other in parameters, evolution characteristics and manifestations of sunspot-forming activity. During the "lowered" epochs of SA the average smoothed areas of sunspot groups are essentially lower; the number of large size and complexes magnetic configuration sunspot groups significantly decreases. The complete cycle, which unites two transitional periods and both epochs of SA (observed one, thus far) is ∼140 years. Epochs "lowered" SA (12–16 and 24 – four following solar cycles) are characterized by a larger fraction of the small quite sunspot groups and by the, correspondingly, lowered level of flare activity; in the low cycles a quantity of powerful solar flare events significantly decreases and, as a result, it leads to a small quantity of large magnetic storms, then the number and duration relative to quite geomagnetic periods sharply increases. Before each epoch changes in the mode of magnetic fields generation in the solar convection zone occur. Such changes occur within 1 ± 0.5 solar cycles. In the transition periods (10–11, 16–17–18 and 22–23 solar cycles) can appear deviations from the observant rules, the number of gigantic sunspot groups sharply increases, and are achieved, apparently, the most extreme flare events (27.08–2.09.1859 in 10-th solar cycle; 1–15.06.1991 in 22-th; 28.10–4.11.2003 – 23). Solar research space methods allow us to examine the details of this transitional period of the magnetic field reconstruction to the epoch of "lowered" solar activity and getting highlights of the first solar cycle (24) of this epoch.

The talk of Professor J.-P. Rozelot (University of Nice, France) reviews a brief but comprehensive history of solar diameter measurements. The first precise determination has been made by French school of astronomy around 1650. Today, accurate observations of this shape made from space, seem to achieve the required sensitivity to measure faint deviation in sphericity and their temporal changes. A shrinking or an expanding shape is ultimately linked to solar activity, as gravitational or magnetic

fields, which are existing mechanisms of strong energy during a solar cycle, which lead to distinct perturbations in the equilibrium solar structure and changes in the diameter. The possibility that the Sun's radius is changing, even at a faint level, is certainly one of the most important basic pieces of astrophysical information. Regarding this issue, the wavelength dependence has been poorly examined up to now. Other available observations, from X-EUV up to radio, typical wavelength dependence can be found, reflecting the different heights at which the lines are formed.

The talk of Professor C. Denker (Leibniz Institute for Astrophysics, Potsdam, Germany) considered high-resolution observations of solar eruptive events. Solar eruptive events, including erupting filaments, surges, flares, and coronal mass ejections, are prominent examples of dynamic Sun. This review focuses on photospheric and chromospheric observation with high spatial, temporal, and spectral resolution of the three-dimensional flow and magnetic fields associated with solar eruptive events. Multi-wavelength and multi-instrument observations with next generation of ground-based solar telescopes and their advanced instrumentation have the potential to reveal highly energetic physical processes on the Sun. These new capabilities to investigate magnetic fields, complex plasma flows, accelerated particles, and thermal properties will be illustrated with data of the Vacuum Tower Telescope and 1.5-meter GREGOR solar telescope at the Observatorio del Teide, Tenerife, Spain. In combination with synoptic data both from ground and from space, solar physicists have now tools at hand to make progress towards a comprehensive description of solar eruptive events effectively aggregating their global properties as well as their highly dynamics fine structure.

A special place at the conference was taken by a cycle of reports by Professor L. I. Dorman (Israel Cosmic Ray and Space Weather Centre, Golan Research Institute, and Israel Space Agency) on the impact of cosmic rays (CR) on the condition of space environment, about their influence on operation of satellites, on technological processes, the biosphere and human health, on climate of Earth, and about the 5-step system of space weather monitoring and forecasting, operating in Israel.

In the first report (co-author E. Babaev – Shamakhy Astrophysical Observatory, ANAS, Azerbaijan) has shown that satellite anomalies (or malfunctions), including total distortion of electronics and loss of some satellites cost insurance companies billions of dollars per year. Now, when a great number of civil and military satellites are working continuously, the problem of satellites becomes very important. In their talk the authors consider only satellite anomalies not caused by technical reasons: the total number of such anomalies are about 6000 events, and separately for high and low altitude orbit satellites (5000 and 800 events, respectively). No relation was found between low and high altitude satellite anomalies. Daily numbers of satellite anomalies were averaged using a superposed epoch method around sudden storm commencements and solar proton event onsets for high (>150 km) and low (<1500 km) altitude orbits revealed a big difference in behavior according to the orbital characteristics (altitude and inclination). The authors also consider the influence of CR on the frequency of gene mutations and the evolution of the biosphere and civilization (if there were no CR, the Earth's civilization would have started only milliards later). Arguments about the influence of CR on space technologies and radiation effects from solar and galactic CR in dependence of cut-off rigidities and altitude, influence of the magnetic storms accompanied by CR Forbush-effects on people's health (increasing

frequency myocardial infarction and brain strokes), increasing frequency of car accidents (possible through people factor), increasing frequency of malfunctions in railway operation (possible, through geomagnetically-induced currents) and in other ground technological systems were adduced.

In the second report the authors consider the effects of CR and some other space phenomena on change in the Earth's climate. It is well known that the system of internal and external factors affectting the Earth's climate is very unstable: decreasing of planetary average annual temperature leads to an increase of planetary snow surface, and decreasing of the total annual solar energy input into the system decreases the planetary temperature even more. And inverse: increasing planetary temperature leads to an decrease of snow surface, and increasing total solar energy input into the system increase the planetary temperature even more. From this follows that even energetically small factors acted long time in one direction may have a big influence on climate change. In the author's opinion, the most important of these factors are CR (mostly through its influences on planetary cloudiness especially low clouds on altitudes smaller than 3 km) and space dust through influence on the flux of solar irradiation and formation of clouds (these actions are in one direction). Interactions of CR particles with dust granules decreases their dimensions what increased effectiveness of their actions on clouds. It is shown that very big changes in climate were caused also by some rare phenomena such as the impact of asteroids and nearby supernova explosions with great influence on the biosphere. The authors also discuss the problem of the forecasting of global climate change which is especially important to protect the world population from climate catastrophes.

In the third report Professor L. Dorman considered the views on monitoring space weather by CR and the use of on-line CR data to predict space phenomena dangerous for satellites electronics systems and the health of astronauts in space and the health of crew and passengers in commercial aircraft at altitude >10 km. Also some rare cases of technology and the health of the ground based general population. Also the prediction of the role of CR and other space weather factors on climate change and influence on agriculture. The author allows for the possibility of proton events of S5–S7 (it has not yet occurred in real history) and estimates consequences of such radiation storms. The problem is how to forecast these dangerous phenomena exactly and accurately. The forecast of such extreme situations can be monitored in the Cosmic Ray Warning System program (5 step) which was developed and checked and tested in the Emilio Serge' Observatory of Israel Cosmic Ray and Space Weather Center (Mt. Hermon, 2050 m above sea level, cut-off rigidity 10.8 GV). The programme starts to work when the first protons of very high energy arrive and are detected in the space environment.

In the fourth report on the key scientific problems of CR history (together with I. Dorman, Institute of History of Science and Technology of the RAS, Russia) the authors reviewed the history (230 years) of the research and study of CR from the question of what are sources of ionization of air up until the current research on influence on climate published in their monograph entitled "Cosmic Ray History" (Nova Publisher, New York).

The complicated problem of the investigation of climate changes in the past and their possible reasons was reviewed in the talk of Professor V. Dergachev (Ioffe Physical-Technical Institute, Russia). The Earth's climate varies on all time scales, from regional to global. Large scale climate variations in the past can be related

to changes in Earth's orbital cycles. Assuming that the radiation of the Sun is the main source of power and impact on the Earth's atmosphere and climatic system, it is possible to consider changes in the earth's orbital parameters: eccentricity (a cycle ∼100 kyrs), obliquity (∼41 kyrs) and precession (∼19–23 kyrs). This report presents the results of the analysis of climatic characteristics and change of climate mainly as result of natural processes on time scale covering the last s hundreds and thousands of years. The report focused primarily on these themes: the analysis of instrumental and historical data on solar activity, including Maunder and Spoerer minima and climate changes, to investigate the short-term and medium-term cyclical variation in these data; high-precision records of cosmogenic isotopes ^{14}C and ^{10}Be from tree rings and ice core of known data give the possibility to study medium-term and long-term variations in solar activity and climate over recent millennia; paleoclimatological evidence presents the past influence of solar variability on Earth's climate, showing the effect of changing solar forcing on a range of different time scales. The role of solar variability as a forcing mechanism of past, present, and future climate change still raises many questions. It is necessary to stress that we are still far away from a complete understanding of all the physical processes and feedback mechanisms that are involved in potential soar forcing of climate change.

In the report of L. Ledentsov and B. Somov (Sternberg Astronomical Institute MSU, Russia) based on modern solar observations the current state of affairs in magnetohydrodynamic theories and models for large-scale high-speed plasma flows in solar flares is reviewed. The large scale structure and dynamics of coronal plasma flows, as seen in TUV and soft X-rays, can be explained in terms of 3D reconnection at magnetic separators in the corona. More specifically, this reconnection is determined by the large-scale photospheric flows mainly of two types. First, the shear flows, which are parallel to the photospheric neutral line, increase the length of field lines in corona with an excess of magnetic energy. Second, the converging flows, directed to the neutral line, create the preflare slowly-reconnecting current layers in the corona and provide an excess of energy sufficient to produce a large flare. During the flare, both excesses of energy are released mainly as fast flows of coronal plasma as well as powerful heat fluxes and accelerated particles. The impulsive heating of the upper chromosphere creates a fast expansion of high-temperature plasma upwards into the corona, called the chromospheric "evaporation".

In the joint report of B. Shergelashvili and H. Fichtner (Austrian Academy of Science) questions of the low-frequency boundary of Sun-generated magnetohydrodynamic turbulence in the slow solar wind were considered. Via an analytical and quantitative treatment of the problem it was shown that a truncation of the wave spectra from the lower frequency side, which is a consequence of the solar magnetic structure and cyclic changes, result in a significant reduction of the heat production and accelerate rates. An appropriate analysis is presented regarding the link of the considered problem with existing observational data and slow solar wind initiation scenarios.

On the basis of data on distribution of a solar wind magnetic field near Earth (hourly average data from the OMNI 2 database for 1970–2014) in A. Asgarov's talk (Shamakhy Astrophysical Observatory, ANAS, Azerbaijan), it was confirmed that in distribution of interplanetary magnetic field values, two peaks that reflect asymmetry in the inward–outward polarity are accurately traced.

The talk of Professor I. Andronov (Odessa National Maritime University, Ukraine) with co-authors consider the question of variability of solar-type stars and related objects. The algorithm for time series analysis of the multi-component multi-channel data with (generally) non-regularly spaced signals are reviewed, as well as the applications to concrete variable stars of different types and evolutionary stages. The total numbers of stars studied exceed 1900. The methods are based on statistically optimal non-linear (global and local) approximations of the periodic, multi-harmonic, multi-periodic, quasi-periodic, transient-periodic and a-periodic (flares, shot noise etc.) signals. They are based on the complete form of the matrix of normal equations, generally talking into account the covariation matrix of the statistical errors of individual observation. This approach allows us to improve the "signal-to-noise" ratio typically by few dozen per cent, but sometimes even by a factor of few times. The stars are observed at space and ground-based telescopes, some of them have been monitored for dozen and even hundreds of nights. The ILA (Inter-Longitude Astronomy) project contains few directions: "Superhumper" (processing accretion disks, quasi-periodic and transient periodic variations in nova-like and dwarf nova systems), "Polar" (25 types of variability of magnetic cataclysmic variables – classical, asynchronous and intermediate polars), "Stellar Bell" (asteroseismology of pulsating stars, mainly of types RR, RV, SR $<$ V), "Eclipser" (classical EA, EB, EW stars with migrating spots, "direct impactors" (V361 Lyr-type stars), eclipsing magnetic and non-magnetic stars, "New variable" (semi-automatic classification of new variable stars). Separately discussed long-term modulations of cataclysmic variables characteristics and of solar-type activity of Roche-lobe-filling red dwarf.

A number of reports on various questions of solar physics were presented by colleagues from scientific institutions of Azerbaijan.

Professor J. Gulu-zadeh (Baku State University, Azerbaijan) proposed a numerical method of measurement and the analysis of the fine structure of the weak and moderated Fraunhofer lines profiles. The digital spectral materials obtained by rapidly scanning double monochromators high dispersion and high resolution have been used. It was shown that with increase in the equivalent widths of the lines integral and residual asymmetries of the profiles grow noticeably and with the increase in the effective formation depth of lines integral and residual asymmetries of the line profiles decrease noticeably. It is in fine agreement with the results of intensity dependence of asymmetry.

The Shamakhy Astrophysical Observatory submitted a number of reports: on the role of spicules in heating and mass balance of the solar corona (Dr. S. Sabirov), about features of light curve types of sun-like pre-main sequence stars (Professor N. Ismailov), about quasi-cyclic variability in the emission lines of T Tau star (Dr. O. Khalilov), about variability in the spectra of the sun-like young star RY Tau (G. Bahaddinova).

The home site of the conference can be viewed at http://sdf.gov.az/conferences/sun2015/. Papers presented at the Conference will be published in a special book after peer reviewing.