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OPTICS IN THE GLOBAL CHANGES OF ENVIRONMENT

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Abstract—The results of the works performed in the field of the most actual problems of physics and optics of the solar–terrestrial links have been analyzed. This is the problem of energy in the ionospheric physics, considered because space monitoring of the solar radiation fluxes and the precipitating corpuscular (mainly electrons) fluxes keV energies from radiation belts ionizing the upper atmosphere is still absent. The permanent solar monitoring at the main part of the ionizing radiation spectra 0.8-115 (119) nm does not exist. In S.I. Vavilov State Optical Institute (SOI) the apparatus for the Space Solar Patrol (SSP) has been developed in the period 1996-2005 years which includes multiyear experience of developing such apparatus. The base of this apparatus is the use of unique detectors of ionizing radiation – the open secondary electron multipliers, which are "solar blind" to near UV, visible and IR radiations of the Sun, and new methodology of these solar spectroradiometric absolute measurements. These are the problems in the theoretical models of transformation of the solar flare energy and corpuscular preipitation into the microwave ionospheric radiation. Finally, this is the main problem of present day natural science: the physical mechanism of the solar–terrestrial links as applied to the explanation of the detected correlations in the Sun–biosphere and the Sun–weather systems. A unified novel physical (radiooptical) trigger resonance mechanism for controlling the processes in the lower atmosphere and biosphere (including human being), dependent on the level of solar and geomagnetic activity and related to the ionospheric microwave radiation, has been considered.

Key words: solar-terrestrial links, microwave emission of ionosphere, heliogeobiocorrelations, global warming, solar-weather and solar-climate problems

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1. Introduction

For the last decades, physics of the near-Earth space has been of increased interest. Physics of the upper atmosphere (thermosphere) and ionosphere has been of not only scientific but also practical interest because orbits of long-term manned spacecraft and most satellites cross precisely ionospheric altitudes. The ionosphere is the medium responsible for radio propagation and, consequently, quality of radiocommunication, radiolocation, and radionavigation. The density of the upper atmosphere affects the stability of orbits of spacecraft, especially of large orbiting stations. This density and the state of the electron–ion component of the ionosphere very strongly depend on the degree of solar and geomagnetic activities, especially intensely increasing during solar flares and geomagnetic storms. An additional energy is usually introduced by high energy particles: quanta of soft X-rays and extreme ultraviolet (EUV) radiation during solar flares and, first of all, keV electrons, precipitating from the Earth radiation belts and coming immediately from the magnetosphere, during geomagnetic storms.
The following problems of the solar–terrestrial links have been solved during this period [1]:
(i) Production of ions and optical excitation in the Earth's upper atmosphere with regard

to new processes described by the physics of atomic collisions, specifically by the Auger effect and double photoionization [2-5]. This was of prime importance for creating the model of a sudden ionospheric disturbance (SID) caused by a solar flare;

(ii) Generation of a microwave emission (during the excitation of Rydberg states by fast ionospheric electrons) in the upper atmosphere, which made it possible, first, to distinguish the physical mechanism in the Sun–biosphere problem [6, 7] and, second, to develop a new approach to the physics of the action of solar and geomagnetic activities on weather and climate [8, 9].

The studies of the role of variations in solar and geomagnetic activities in terrestrial phenomena have attracted attention of astrophysicists, geophysicists, meteorologists, and biophysicists for a long time [10-14]. However, before the appearance of satellites and spacecraft, the main results were obtained only from the correlation between effects in the biosphere (including human being), climate, and weather and the so-called proxy indices of solar activity. Such data could be obtained at that time at ground based observatories. But, the problem of understanding physical mechanisms (the main problem of solar–terrestrial links) has not been solved for many decades after the launch of rockets, satellites, spacecraft, and manned orbiting stations. In our opinion, such a situation is caused by the absence of permanent monitoring of the main solar activity parameter, namely, the spectrum and flux of the ionizing (X/EUV) solar radiation and also the spectrum and flux of the ionizing electrons, precipitating from radiation belts[15-18]. Such a monitoring is absent only because it is technically and methodologically difficult to measure spectroenergetic characteristics of the ionizing solar radiation on spacecraft [15]. This ionizing radiation includes and soft X-ray and EUV radiations and can be measured only out of atmosphere – in space.

The most important problem of the up-to-date science is to understand the basis causes of global changes in environment. The global warming observed during the several past decades presents a real danger for the mankind. Till present the predominant point of view has been that the main cause of the increase in the mean surface air temperature is the increase in concentrations of the anthropogenic gases first of all carbon dioxide CO_2 and methane CH_4. Indeed, from the beginning of nineteen century the concentration of CO_2 in the atmosphere has been growing and now it exceeds the initial level by the factor of 1.4 and the speed of this increase being growing too. This was the reason of international efforts to accept the Kyoto Protocol which limited the ejections of greenhouse gases. However, there are premises which show that the influence of solar variability on the climate should be taken into account in the first place [19].

Elaboration of the mechanism of solar and geomagnetic activities influences on the low atmosphere (including weather and climate) is one of the most complicated problems of the solar-terrestrial physics [1]. But there are also many problems in the study of anomalous aerospace phenomena [20]. For the practical purposes it is very important to understand what solar variability contributes to the global climate changes, including growth of the mean surface air temperature observed in XX century.

The aim of the work is to indicate that it is important to specifically take into account the state of the ionosphere (from the variations in the flux of energetic ionospheric electrons to the intensity of microwave emissions from the Rydberg levels excited by the impact of these electrons in gases of the upper atmosphere) when solving the Sun–weather and Sun–biosphere problems and in the entire physics of solar–terrestrial links. We note once more that it is necessary to obtain still absent information about real current values of the fluxes of the solar ionizing radiation and precipitating electrons when studying these problems of fundamental and practical importance.

2. The physics of solar-terrestrial links and Space Solar Patrol Mission

Modelling of the processes of ionization and optical excitation in the terrestrial upper atmosphere experiences permanent problems with more accurate consideration of energetic balance in the Earth's aeronomy [21].

The following aspects of the energy balance problem were considered in our works:

(i) the role of newly introduced processes of ion production (including the Auger effect and double ionization), optical excitation (including excitation by photoelectrons and secondary electrons, taking into account Auger electrons in their spectral distributions), and excitation of Rydberg states [3, 4];

(ii) the contribution of the additional source of ion production: the solar radiation, resonantly scattered in the geocorona, in the series of lines in the EUV spectral region [22]. The role of Auger electrons is of special importance [15, 23]. Indeed, the main increment of the absolute flux of the solar ionizing radiation during a flare is observed in the shortest wavelength (X-ray) range. In this case each act of photoabsorption is accompanied by not only the photoeffect but also the Auger effect resulting in the production of Auger electrons with energies of 300–500 eV. These electrons can several ten times ionize and excite atoms and molecules of all atmospheric gases to the optical and Rydberg states. That is why simulation of ionospheric parameters using ion production rates, calculated within the scope of a simplified method of effective ionization cross-section, gives too approximate results. Thus, in [24] it was indicated that the effective cross-section method gives a factor of 1.5–2 larger values at altitudes lower than 130–150 km in the ionospheric E region (since preliminarily calculated spectra of photo- and Auger electrons are taken into account) and a factor of up to 1.5–2 smaller values at altitudes of 150–250 km in the F1 layer as compared to the results of exact calculation. In this case the rates of excitation of optical, UV, and microwave emission by electron impact cannot be calculated without constructing the entire spectra of photoelectrons and auroral electrons with energies from the excitation or ionization threshold to several hundreds of electron volts.

Under night time conditions, the ionosphere is also controlled by the solar EUV radiation. The observations of the cosmonauts in the long-term flights enabled to discover the large role of the resonance scattered in the geocorona of EUV emission of solar irradiation at the night side upper ionospheric ionization and optical excitation [22, 25, 26]. Such a manifestation of the solar flare effect on the nocturnal terrestrial upper ionosphere up to 20 % in electron density has been detected for the first time. It was found out that previous calculations of the nocturnal photoionization of the upper atmosphere ignored the presence of a strong anisotropy of radiation from the geocorona, primarily over the zenith angle. The most intense radiation is incident from above on the nocturnal ionospheric F-region from the dawn segment at zenith angles close to 90 degrees. This is a key feature in consideration of the additional ion formation in the upper atmosphere, because, at the zenith angles of 70-90 degrees, the ionizing radiation with wavelengths of 30-91 nm is totally absorbed at the F-region altitude.

Moreover, consideration was given to the existence of the upward positive double charged ions of atomic oxygen ion flux from the F-region to the plasmosphere during the first tens of hours after a strong magnetic storm [25-28]. This results in a significant increase in the ionic density in the geocorona: up to 100-fold at altitudes higher than 1600 km (see data of GEOS-1, DE-1, EXOS-D (AKEBOHO), Interkosmos-24 and Interkosmos-25. This ion layer mainly contributes to the EUV geocoronal ionizing radiation (at the lines 30.4-, 50.7-, 70.3- and 83.3- nm)) [22]. The measurements at this spectral range were carried out for terrestrial plasmosphere at the spacecraft IMAGE [29]. A similar scheme of the effect of the resonantly scattered solar emission on the excitation and ionization of the night time polar ionosphere was proposed in [28]. Consequently, enhancement of the effects of solar-terrestrial links under night time conditions can also be regulated by the level of solar and geomagnetic activities via the ionospheric microwave emission in quantum transitions between the Rydberg states. In this case such night time states are also excited by ionospheric photoelectrons, including those produced by resonantly scattered radiation during flares [30].

The soft X-ray (0.1-10 nm) and EUV (10-125 nm) ranges are among the most geoeffective parameters of the solar electromagnetic spectrum. Precisely this radiation, being completely absorbed in the Earth's upper atmosphere, is responsible for the formation of the ionosphere and the energy of the majority of the main processes at altitudes higher than 60 km. This is related to the fact that the flux density in this range of the solar spectrum is most variable during the 11-year cycle, 27-day rotation, and (above all) solar flares [31]. Solar flare as the highest manifestation of solar activity results in the emission of X rays from the entire disk, which is higher than before flare by two-three orders of magnitude. In the EUV range, the total density of such a flux increases approximately twice during solar flares, but this is a very substantial factor that changes the state of the Earth's ionosphere. The energy fluxes of all other components of flare phenomena - solar protons and electrons, solar wind, and coronal mass ejections - are substantially lower. Thus, the solar radiation in the spectral region from 0.1 to 200 nm gives at the Earth's orbit an energy flux of 0.1 $W{\cdot}m^{-2}$. In this case, the flux in the L_α line of the hydrogen atom (λ = 121.6 nm) on the average equals 0.004 $W{\cdot}m^{-2}$, the flux of solar protons - solar cosmic rays (SCR) is 0.002 $W{\cdot}m^{-2}$, the flux of galactic cosmic rays (GCR) is $7{\cdot}10^{-6}$ $W{\cdot}m^{-2}$, and, finally, the energy flux transported by the solar wind is $3{\cdot}10^{-4}$ $W{\cdot}m^{-2}$ [32].

In recent years there has been a sharp increase in the interest in and need for monitoring of the solar activity and its effects in phenomena on Earth. These problems are under investigation also in the frame of the international TIGER (Thermospheric / Ionospheric Geospheric Research) Program [33-36]. Though the first impact of space weather on the distortion of telegraph communication has been recorded in 1860, there is now increasing interest in the societal impact of the solar and geomagnetic activity.

The results of this spectral monitoring may be a source of development of studies in several sciences such as [18]:

- solar physics (the state of all regions of the solar atmosphere),
- meteorology and physics of the atmosphere (impact of shortwave solar activity on the global changes, weather and climate including the effects of atmospheric electricity),
- aeronomy, cosmonautics (influence of solar activity on the density of the upper atmosphere and the drag of space vehicles, on the parameters of their atmosphere and satellite anomalies),
- radiophysics (determination and prediction of the planetary ionospheres and conditions of radio wave propagation),
- heliobiology (the possible role of the solar variability in biology and medicine),
- possibly seismology and probably sociology.

Space Solar Patrol will be important for interplanetary flights also because it provides a monitoring of solar activity during interplanetary expeditions (for example, to Mars). From the very beginning of the flight after space ships leave the terrestrial magnetosphere (at the distance of 10 Earth radii) the cosmonauts would be subjected to the action of the high-energy solar protons and electrons in the periods of strong flares. The flashes of these corpuscles may be predicted using also the information of the monitoring of the solar X-ray and extreme UV radiation, because the wave radiation arrives to the Earth orbit across 8 min after the flare, whereas high-energy particles arrive across by more than 20 h later. So there is time (and for the Mars orbit it is by a factor of 1.5 longer) to predict dangerous impact and to protect cosmonauts [37].

At present, the permanent monitoring of solar X-rays in the range λ less than 0.8 nm, separated into two spectral intervals: $\lambda\lambda$=0.05–0.4 and 0.1–0.8 nm, was set up in the years of the space era. This was able to be done using comparatively simple radiation detectors—ionization chambers with filters consisting of beryllium and aluminium foils, installed in 1960 on a satellite of the SOLRAD series. In all subsequent years, measurements in these ranges were made in the constant patrol regime on spaceships of the GOES series, launched into geostationary orbit. All attempts to set up constant monitoring of soft X-rays and extreme UV radiation from the entire solar disk in the spectral region 1–120 nm produced only scattered short-term measurements both from spaceships and in rocket experiments. The longest-term and most continuous monitoring of solar flux in the EUV was carried out on the SOHO (SOlar and Heliospheric Observatory) spacecraft, beginning in 1996, and by the apparatus of the SEM (Solar EUV Monitor) in two sections of the spectrum: 25.5–34 nm, including the strongest line of the helium ion, at 30.4 nm, and in a wide range (behind an aluminium film) from 5 to 80 nm. However, not all these spectral-measurement intervals were implemented, and this does not provide, for example, information on the flare increase of soft X-rays (λ<5 nm) nor on the spectrum and flux in the entire range of λ<120 nm, which is important for aeronomy. Attempts have been repeatedly made to advance into the spectral region of soft x rays, close to 0.8 nm, where patrol measurements long ago were set up on spacecraft GOES. Measurements were set up in the last decade on satellite SNOE (Student Nitric Acid Explorer) with radiometer Solar XUV Photometer, making it possible to monitor fluxes in three spectral intervals in the range from 3 to 20 nm, and on satellite SORCE (Solar Radiation and Climatic Experiment), where the apparatus of the XUV Photometer System was used to make measurements in the range from 1 to 34 nm in ten spectral intervals, as well as carrying out monitoring in the L_α line of the hydrogen atom (λ=121.6 nm) and in the spectral interval 115–195 nm with a resolution of 1 nm. A disadvantage of these two satellites is that there are major interruptions in operation (the measurements on SNOE were made only several times in a day, while SORCE measures up to 60% of the time in each orbit), and this does not make it possible to monitor the spectrum of powerful flares on the Sun. Episodic measurements in wide spectral intervals 0.3–2.5 and 0.3–12 nm, as well as in the Lα line are carried out on the Russian satellite CORONAS-F with filter apparatus SUFR (Solar ultraviolet radiometer) and VUSS (Vacuum ultraviolet solar spectrometer).

The complete spectrum of the sun in the region from 0.1 to 195 nm is measured by the SEE apparatus on the TIMED satellite for approximately 4 min out of each 97 min (the time to complete an orbit). As can be seen, because the solar measurement cycle is very limited in time, the SEE apparatus is not intended for monitoring solar flares [35]. Among experiments, the most metrologically suitable for absolute measurements is the SolACES apparatus (Solar Auto Calibrating EUV/UV Spectrometers) intended for operation on the International Space Station for 15 min on each orbit. Measurements are made in the wavelength interval from 17 to 220 nm, with spectral resolution from 0.3 to 0.9 nm [36]. On the subsequent GOES apparatus, in addition to the existing X-ray detector (X sensor), it is planned to install a new device—a detector of extreme-UV solar radiation (EUV Sensor). This device is intended to measure the solar ionizing radiation in five broad channels [34]. EUV Sensor makes measurements of the solar radiation with levels from 1/10 of the solar minimum to a level 10 times greater than the solar maximum. The recording is done every 10 sec, with an error of about 10%. The detector includes a diffraction grating, thin-film filters for suppressing undesired radiation, and silicon diodes, which are used as detectors of ionizing radiation, with tantalum sputter coating to prevent the action of damaging radiation. However, there are complications in solving such questions as suppressing visible radiation by the existing filters in two of the five channels (EUV-A and EUV-B) and at the same time making it possible to measure the flux in these channels. This difficulty is associated with the low level of solar radiation in this spectral range. As a possible solution of the problem in these channels, it is planned to use a solar blind detector with a photocathode. In this case, an incident photon removes a photoelectron out of the photocathode, and the electron is accelerated and directed toward the diode. The diode current caused by the accelerated photoelectron is much greater than with direct detection of a quantum. Such materials as gold, aluminium, tungsten, and platinum are being considered as the photocathode, but their solar blindness is insignificant. It is planned to simultaneously operate two GOES spacecraft to ensure cross-calibration of the instrument with the EUV Sensor. With each subsequent launch of a new GOES spacecraft (every 2–5 years), the new calibration of EUV Sensor will be applied to the complex of the measured data. A similar radiometer (Monitor-FOKA) for monitoring the flux of extreme-UV solar radiation in three broad spectral intervals (λ<11 nm, 27–37, and 116–125 nm) discriminated by filter films, is installs on the Russian satellite CORONAS-Foton. Naturally, there are the same problems with insufficient solar blindness of the silicon photodiodes used in this apparatus [16].

Interesting measurements are planned on the Proba-2 satellite with the Lyra apparatus [38]. This involves not only constant monitoring of the flux level in the L_α line of the hydrogen atom, but also measurements in two spectral intervals: 1–20 and 17–70 nm. A promising plan has been developed for equipping the SOLAR Dynamic Observatory (USA) with the EVE apparatus (EUV Variability Experiment), which includes two devices: the Multiple EUV Grazing spectrograph, developed for the spectral region from 5 to 105 nm, with a resolution of 0.1 nm, and also for the X-ray region $\lambda<7$ nm, with resolution better than 1 nm, and an EUV spectrometer similar to the SEM apparatus on the SOHO spacecraft, which will have three separate spectral ranges: 0.1–7, 17–34, and 58–63 nm. It is not planned to monitor the solar flux in the region from 105 to 120 nm.

The results of this analysis thus show that an experiment is needed that totally monitors the variations of the solar short-wavelength radiation (including measurements in the entire spectral interval 0.14–135 nm, with sufficient spectral resolution for solar–terrestrial physics of about 1 nm, in the constant regime with continuous scanning of the spectrum every 72 sec, which is close to the duration of both the subflare and the pulse phase of powerful flares), and this is the Permanent Space Solar Patrol that we proposed [15, 17, 39, 40]. The signals from the radiation and from charged particles are separated by comparing the readings of the solar sensor with the readings of another sensor, placed at a nearby pitch-angle and recording only the charged particles.

An important point is the degree of solar blindness of the ionizing-radiation detectors. It is highest in the SSP apparatus (up to 10^{-10} of the working section of the spectrum even at 270 nm). Figure 1 shows a comparison of the solar blindness, calculated using the quantum yields of various photodetectors [15, 16, 38, 41]. It can be seen that only the beryllium oxide photodetector used in the SSP apparatus has sufficient solar blindness to allow the use of filter films, in which holes are virtually unavoidable. This answers the question of why permanent monitoring of solar ionizing radiation has not yet been set up in the range from 0.8 to 119 nm. Actually, besides the usual complications of an optical space experiment involving absolute measurements of ionizing radiations (windowless optics, fogging, scattered light, support against fluxes of hard and penetrating radiation) in the wavelength range of EUV radiation, the photodetectors used here need to be substantially blind to soft UV, visible, and IR radiation. The fluxes of such radiation from the Sun and the underlying surface on the daytime side of the earth are several orders of magnitude greater than the radiation to be measured. This imposes requirements on the absence of holes (including new holes that open up in vacuum during space flight) in the filter films, as well as on the absence of gaps where the filters are joined to the diaphragm-holders at a level better than 10^{-8} of the working area of each filter.

This also determines the limitation on the contribution from light scattered in the solar spectrometers. Such requirements on the radiation detectors, the filters, and the scattered background light were hard to satisfy in most space experiments that were carried out to monitor the absolute fluxes and the spectral content of the solar soft X-rays and EUV radiation that ionizes the entire region of the Earth’s upper atmosphere. In order to increase the signal to noise ratio of the photodetector-multiplier output, it is first of all necessary to raise the quantum yield of the photocathode. As one of the ways of decision of this very difficult problem we can offer to use, for instance, photocathode with multiplication of photoelectrons by method described in [42], when were used detectors of nuclear radiation made of porous dielectrics. These detectors have high temporary resolution (up to 10^{-10} s) but are usually used to registrate particles with energies ~10-100 keV.

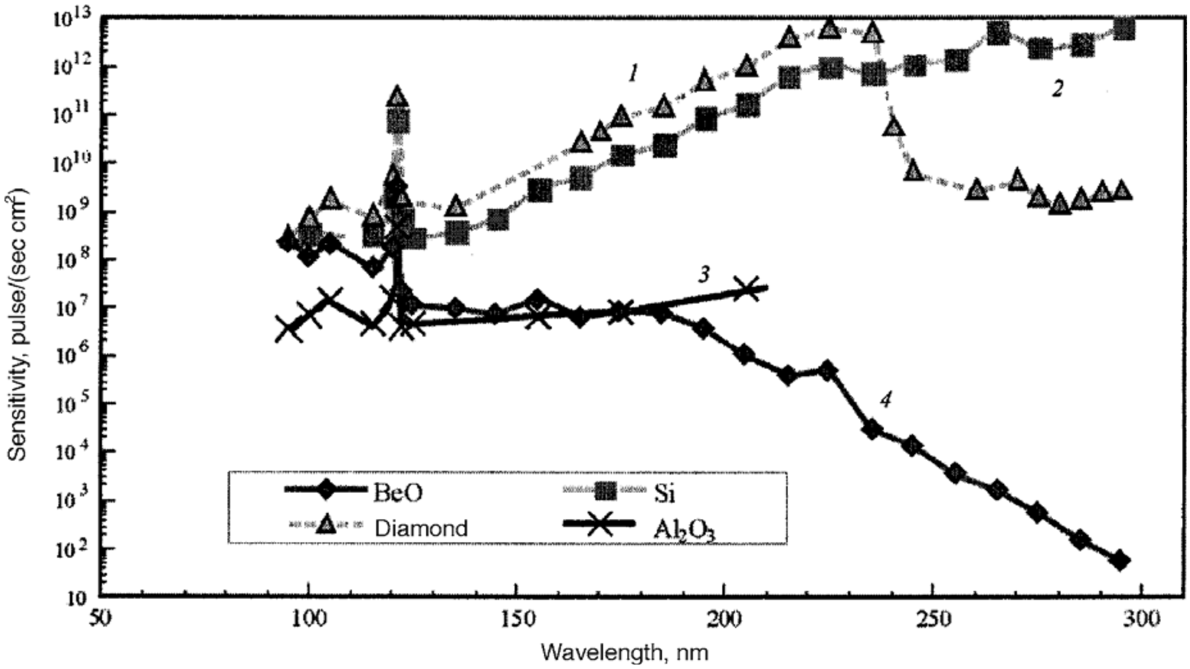

Fig. 1. Comparison of solar blindness of various photodetectors when the spectrum of the quiet sun is being recorded [16]: 1 - diamond [38], 2 - silicon [38], 3 - aluminium oxide Al_2O_3 [41], 4 - beryllium oxide BeO in the SSP apparatus [15].

The apparatus of the SSP mission involve the simultaneous use of two spectrometers and a radiometer, and a special algorithm is used for separating signals from radiation and charged particles precipitating from the earth radiation belts. In this case, the spectrometers measure a detailed source function and its variations, whereas the filter sensors give reference information for selecting signals of the solar radiation and for obtaining its absolute intensity allowing for the stray light in the spectrometer (with due account of the source function and the presence of 20 wave bands isolated by foil, thin-film, and crystal filters). The signals of the radiation and charged particles are isolated by comparing the readings from a solar sensor with those of another one mounted at a close pitch angle, which detects the charged particles.

Finally all spectrometers and radiometer use the same open secondary electron multipliers (elaborated by the State Optical Institute) with BeO photocathode, which has a large dynamic scope up to 10^7. The latter characteristic enables to carry out the measurements both for quiet Sun and during the very large solar flares. The use of the same multipliers for all the spectral range enables to calibrate the absolute sensitivity of our apparatus in flight on the basis of data of solar short-wave monitoring which already exists.

The apparatus of the permanent solar patrol system for monitoring the solar radiation comprises the following units [15, 39, 40]:

1. A space-based patrol radiometer for the 0.14-157-nm spectral range with sequential separation of 20 bands of different spectral widths using a disk with filters made from thin metal foils, thin films, and optical crystals.

2. A space-based patrol spectrometer for the extreme UV radiation, which measures the solar radiation spectrum in a spectral range from 57 to 153 nm with a spectral resolution of 1.0 nm. The spectral resolution of both spectrometers is chosen taking into account the possibility of isolation of the higher-order spectra from the most intense lines in the solar spectrum. At the same time, it is low enough to enable obtaining a high signal from a faint solar radiation flux (in the region where the continuous spectrum or low-intensity lines dominate) against a background of the stray light in the spectrometer from the strongest lines. A 3600 grooves per mm spherical diffraction grating with a 250-mm radius of curvature, ruled on a gold layer, is used as a spectrum analyzer. This spectrometer also employs a classical arrangement of the entrance

and several exit slits on the Rowland circle at their "middle" position. The spectrum is scanned by rotating the diffraction grating by an angle of ±1.9° relative to its middle position with the entrance and exit slits being slightly displaced from the Rowland circle. The spectrometer is a scanning polychromator which covers a spectral range from 57 to 153 nm by three channels, each one having a bandwidth of about 35 nm and being equipped with its own exit slit and radiation detector. In addition, three more channels are provided: for the 16-34-nm and 28-63-nm spectral regions to carry out trials of the measuring ability of this version of the spectrometer in the given spectral range, and an auxiliary channel for the 195-230-nm spectral region to align the spectrometer under the normal atmospheric pressure conditions. In the "middle" position, the angle of incidence of the input beam is 27°, whereas the angle of the diffracted rays ranges from minus 22.8° to 1.94° in the channels for the vacuum UV spectral region from 16 to 153 nm and amounts to 18° in the channel for the 195-230-nm "air" spectral region. All five channels for the EUV spectral region overlap so that all the most intense and important lines in the solar flux at 30.4, 58.4, and 121.6 nm are detected twice during a 72-sec measuring cycle. They used open secondary electron multipliers (SEM) worked at the Vavilov State Optical Institute.

3. The new design of scanning slitless grazing polychromatic instrument is proposed. It allows the registration of the spectral distribution of the solar irradiance in the spectral range of 1.8 nm - 63 nm to be carried out during 72 s. The concave grating with 600 grooves per mm and with radius R=28080 mm, size S=30×20 mm^2, blaze angle δ=1° ($\lambda\delta$=3 nm) is used. The variable line space enables the focal curve to be placed as close to the exit slits as possible. The spectrum scanning is performed by means of turning the exit slit together with the detector of radiation. In this case the entrance window and the grating are not moved. The grazing angle is 2 degrees.

For reliable registration of the spectrum three channels parallel (λ=1.8-23 nm, 22-63 nm and also 62-123 nm) equipped with two open secondary electron multipliers are used. The forth air channel (119-198 nm) with photoelectron multiplier PEM-142 serves for checking the grating in flight and also for the spectrometer alignment. Calculated spectral resolution is varied from 0.36 nm to 1.56 nm and mainly less than 0.8 nm depending on the wavelength and sizes of exit slits. The error of reading for λ is 0.17 nm because the solar-oriented platform is unstable (the orientation accuracy is about 10 angular minutes).

In the solar patrol set of apparatus described here, several channels are provided for monitoring the stability of its absolute spectral sensitivity. There is plan to carry out absolute spectral calibration of the apparatus using a synchrotron radiation source just before the period of preparation of a spacecraft for its mission. In this case, two ^{55}Fe isotope radiation sources of different intensity will be used in the radiometer in the working spectral region around 0.2 nm. This allows the variation in the absolute calibration at this wavelength to be checked after launching. An additional possibility to calibrate both the radiometer and the EUV spectrometer against the solar radiation with wavelengths longer than 150 nm appears in space. To this end, measuring the solar flux at λ > 157 nm through a quartz crystal is provided in the radiometer, and the long-wavelength measuring channel in the EUV spectrometer is capable of detecting the spectrum up to 153 nm. Lastly, the spectrometer has an auxiliary channel for the 195-230-nm spectral region, wherein the magnitude of variations in solar radiation flux does not exceed several percent during the eleven-year activity cycle and the 27-day period of rotation of the Sun. However, this long-wavelength auxiliary channel enables monitoring the stability of the diffraction grating efficiency without solar flares, because the effect of space factors on a PEM-142 photomultiplier was not found at low orbits, in particular, during the Mir orbital station mission.

At least, with due account of the success achieved to date in the patrol of the ionizing solar radiation at wavelengths shorter than 0.8 nm and longer than 120 nm, we provide a regular reference of our patrol to these data as well.

The optical testing is carried out in the vacuum chamber because the open secondary electron multipliers (SEM) which are used both in the radiometer and spectrometer have to work in vacuum conditions. The chamber for radiometer has a window made of MgF_2, which transmits the radiation of the wavelengths above 113 nm. Wavelength calibration of EUV-spectrometer was made in air channel (No. 6) with a standard lamp DRGS-12 as a source and power supply block SF-46. The fourth and fifth channels are tested using the lamps DAM-25 and DNM-15 in vacuum chamber of the State Optical Institute. The spectrometer resolution $\Delta\lambda$=1 nm. The resolution was determined as a half-breadth at the krypton lamp line (λ=123.6 nm). It should be noted that the intensity scale is logarithmic one. For resolution determination the krypton lamp was taken firstly, because in the region of λ=123.6 nm there is no superposition with another peaks, and secondly, because the spectrum of this lamp is atomic (instead of molecular spectra of hydrogen lamp). We used the 123.6 and 147 nm lines, generated by krypton and xenon lamps, for calibration of the deuterium lamp DNM-15 spectrum by wavelength. The 147 nm line of xenon lamp have much less intensity then 123.6 nm of krypton lamp because firstly, this line has the less intensity and, secondly the photocathode sensibility drops in ten times in the 123 – 147 nm range. So, the calibration of EUV-spectrometer over wavelengths in 4, 5 and 6 channels showed the full conformity of measured and calculated characteristics of the device.

The proposed project is based on utilizing the known experience in development, fabrication, and operation of radiometric and spectral optical-electronic apparatus for measuring the absolute ionizing solar radiation fluxes from satellites, which has been accumulated at S.I. Vavilov State Optical Institute since 1956 [15]. However, the satellites on which this apparatus was installed (the second Soviet satellite-spacecraft launched in 1960, Cosmos-262, 1968/69, and Cosmos-381, 1970/71) did not have solar orientation facilities, and patrol measurements turned out to be impossible. Casual appearances of the solar disk within the field of view of both the spectral and radiometric equipment demonstrated its normal operation and reliable functioning throughout the period of the active existence of the satellites and made it possible to obtain a number of new data on the absolute ionizing solar radiation fluxes and on variations in their intensities during the periods of solar flares [15].

At present there are plans to launch of SSP apparatus at the Russian Module of the International Space Station for experimental operation. However, the plan of placement of OEA on ISS board does not allow to create the Space Solar Patrol in permanent regime due to location of the Station in the shadow side of each orbit. In principle, cost-effective solution of the problem is to launch a series of small sun-oriented spacecrafts at the sun-synchronised orbit. This procedure will provide long-time (no less than two one-by-one 11-years solar cycles) permanent controlling the solar short-wavelength activity, including flare periods.

3. The new physical mechanism of heliogeobiocorrelations

In [6,7] it was proposed and provided substantiation for a hypothesis concerning the mechanism, by which solar and geomagnetic activity (mainly of solar flares and magnetic storms) affects the biosphere, including man. The hypothesis, including a physical mechanism introduced by the author and new for aeronomy, is that high-lying (Rydberg) states of all gases of the Earth's upper atmosphere are excited by ionospheric electrons. Rydberg atoms, molecules and ions of all atmospheric gases emit characteristic radio emission in the spectral range from decimetres to millimetres. This radiation can easily penetrate to low atmosphere and biosphere carrying complete information about the power and duration of solar flare and geomagnetic storms to biosphere. Sporadic rises in the intensity of microwave radiation of ionosphere were registered in [43, 44] at times of solar flares and aurora (geomagnetic storms and substorms). The intensity during periods of flares exceeds usual microbursts of solar origin many times. Microwave radiation of aurora borealis has been registered since 1949 [45].

One of the fundamental problems of modern natural science is the search for biophysical mechanisms by which solar and geomagnetic activity, and especially solar flares and magnetic storms, affect people and the biosphere as a whole. The accumulated experimental material is mainly evidence, at least in indirect form, of the presence of heliogeobiocorrelations. It is obvious that such correlations are very complex because of their multifactorial nature. A similar approach is applicable to other objects of the environment, mainly to the lower atmosphere - its state and variations of the main weather parameters. It is possible that it is this constantly existing microwave ionospheric radiation (similar to the luminescence of the sky) and the detected sporadic increases of its intensity that are the "definite forces in our natural medium that not only control the functional state of each man, but also influence the life of plants and alter the weather and the course of various illnesses [12]."

The energetic of the variations during the period of geomagnetic perturbations of the geomagnetic field itself with respect to the mean value and even more in absolute magnitudes are insignificant. Therefore, the "kT problem" in magnetobiological effects is continually being discussed in the literature [46]. In this connection, there is interest in discussing the arguments in favour of the hypothesis of [6, 7] on the importance in heliogeobiospheric correlations of the contribution of the microwave radiation of the Earth's ionosphere, detected as sporadic microwave radiation when the solar and geomagnetic activity increases [43, 44].

In 1994, we were the first to propose [30] that the fact that the plasma of the Earth's upper atmosphere (and of other planetary atmospheres) unconditionally contains highly excited Rydberg states of atoms, molecules, and their ions should be taken into account in aeronomy and ionospheric physics.. Rydberg states correspond to strong excitation of a valence electron that had been in orbit with high principal quantum number $n>10$. In practice, this is a state of an atomic-molecular particle of any gas of the upper atmosphere close to its ionization potential. These Rydberg states are metastable (long-lived), since most radiative quantum transitions from them have low probability. Transitions from the Rydberg states fill virtually the entire region of the electromagnetic spectrum of the upper atmospheric emissions, beginning from the EUV radiation [47]. According to the selection rules for electric dipole transitions, the allowed transitions will be those for which the orbital-momentum quantum number changes by an amount $l=\pm1$. Therefore, because of the high values of n and hence of l ($l=n-1$ and below), transitions from high l can occur only between adjacent Rydberg states and consequently lie in the rf region.

Specific emissions from Rydberg levels are constantly recorded when the optical radiation of the upper atmosphere is observed [48] as well as in active experiments [49, 50]. These experiments consisted of heating the ionosphere with powerful pulses of radio waves at frequencies of 4.7–6.8 MHz. In response, the ionosphere generated microwave decimetre radiation from the altitude interval from 185 to 240 km, as well as additional emission of the red lines of the oxygen atom. The analysis given in [49, 50] of various ways to generate the detected microwave radiation includes the following: scattering of the Earth's thermal radiation at artificial inhomogeneities of the electron concentration, bremsstrahlung of electrons accelerated by high-frequency plasma turbulence to energies of the order of 10–15 eV, and transitions of the electrons between high Rydberg levels of the molecules of the neutral components of the ionospheric plasma excited when they collide with accelerated electrons, showed that the last of the three enumerated mechanisms is the most probable. It was also emphasized in [49, 50] that the region of artificial generation of microwave radiation coincides in altitude (about 200 km) with the position of the maxima of the altitude profiles of the excitation rates of the Rydberg states, calculated in [51] for the ionosphere under natural conditions. Thus, [49, 50] is the first experimental proof of the excitation mechanism of Rydberg levels by energetic ionospheric electrons proposed in [51].

The excitation rate of Rydberg states increases with the growth of geomagnetic and solar activities in particular during the solar flares (up to 10 times and more) and during the principal magnetic storms (up to 100 times and more). Unlike the auroral zone, where the excitation rate as a rule shows only one main maximum at the altitude about 100 km, during the solar flare there are usually two maxima. The first maximum, connected with EUV solar radiation, occurs at the altitude near 200 km and its value increases during a flare by several tens percents. The second maximum at the altitude above 100 km becomes the main one during the large flare. Its increase comes up to ten times and resulted from the X-ray solar radiation. During the quiet Sun the excitation rate of sum of the Rydberg states exceeds the value 10 $cm^{-3}s^{-1}$ for atoms and molecules of oxygen and 100 $cm^{-3}s^{-1}$ for molecules of nitrogen. During solar flare 2B the integral intensity in vertical column is 10^9 photons cm^{-2} s^{-1}[50]. The centimetre radioemission results from transitions with changing the orbital quantum number on 1, for example in atomic oxygen at n = 10 - 20, and the decimetre radioemission occurs at n = 20 - 40, if n is constant. If $\Delta n > 1$ and $n > 10$, there are the millimetre emissions of ionosphere.

It should thus be assumed that a direct information channel from the lowest layers of the atmosphere and the biosphere itself concerning variations of the solar and geomagnetic activity has been determined. For the biosphere and in particular for the human organism, this information, in the form of flux variations of the microwave radiation, can be just the Agent X that was postulated by A.L. Tchijevsky. It should be emphasized that the sun itself emits microwaves, but this radiation does not directly correlate with the main flare flux—the flux of geoeffective short-wavelength (extreme UV and X-ray) radiation, whose energy is seven orders of magnitude greater than the solar RF flux.

Numerous experimental and theoretical papers on studies of the mechanisms by which millimetre and centimetre radiation acts on a living organism emphasize the resonance character of the response of biological cells and erythrocytes to such irradiation. As long ago as 1948 in [52] it was detected that there is the influence of microwaves (λ=3–5 cm) on the brain. So, there are several works about the theoretical and experimental resonance of living systems: biological cell at $f = 41.782 \cdot 10^9$ Hz (λ=7.2 mm) and $f=83.564 \cdot 10^9$ Hz (λ=3.6 mm); DNA-spiral at $f=4 \cdot 10^{10}$ Hz (λ=7.5 mm); molecule DNA at $f=10^9$ Hz (λ=3 dm), molecule RNA at $f=10^9$ Hz (λ=3 dm), cellular membrane at $f=10^{10}$–10^{11} Hz (λ=3 cm–3 mm), human erythrocytes at $f=10^{10}$ Hz (λ= 3 cm). Consequently, not only cells of the human organism, but also the blood, have resonance microwave frequencies at which the Rydberg ionosphere excited by flares and magnetic storms radiates. Of course, these questions were discussed earlier by A. L. Tchijevsky. He proposed in this case that Agent X is (among other things) ‘‘electric vibrations of a definite frequency’’ [53] and later that the agent of the action of solar activity is in particular millimetre radiation [54]. Recently Russian scientists [55] have discovered that the reason that flares on the Sun and following geomagnetic storms have influence on the cardiovascular system lies in the change of the physical attributes of the blood. During solar flares changes are experienced in human blood viscosity, red corpuscle proportion in the blood, in the concentration of fibrinogen and the aggregation of blood corpuscles and platelets. These processes take place differently in healthy and meteodependent people with cardiovascular problems. In the latter, the blood thickens when magnetic disturbance on the Sun reach the Earth. In the case of healthy people, the organism prepares for the event two days before its advent, immediately after a solar flare. We propose the next scheme of the heliogeobiocorrelations: Fig. 2 [6, 7]. During high solar activity specially flares at the Sun and also large geomagnetic activity (magnetic storms) there are increased fluxes of EUV and X-rays and precipitating particles from geomagnetosphere, which generate the additional ionization of terrestrial ionosphere. This ionization results in production of photoelectrons and secondary electrons and especially Auger electrons. Rydberg excitation of atoms and molecules by these electrons generate microwave monochromatic radiation: (mm, cm, dm), which can produce the resonance reaction of living systems during “unfavourable days” for sick people. It is important that microwave radiation in the system that we proposed is capable of acting as the carrier frequency, with modulation by infrasound and internal acoustic-gravity waves of the upper atmosphere, as well as by vibrations of the background electromagnetic field (Alfven and Schuman resonances at the terrestrial ionosphere), including in the region of biorhythms. This amplifies the influence of low-frequency vibrations of the background electromagnetic field, with its high biological efficiency but low energetics of its action, especially because of the surprisingly strong action on biological objects from the side of microwave radiation [46].

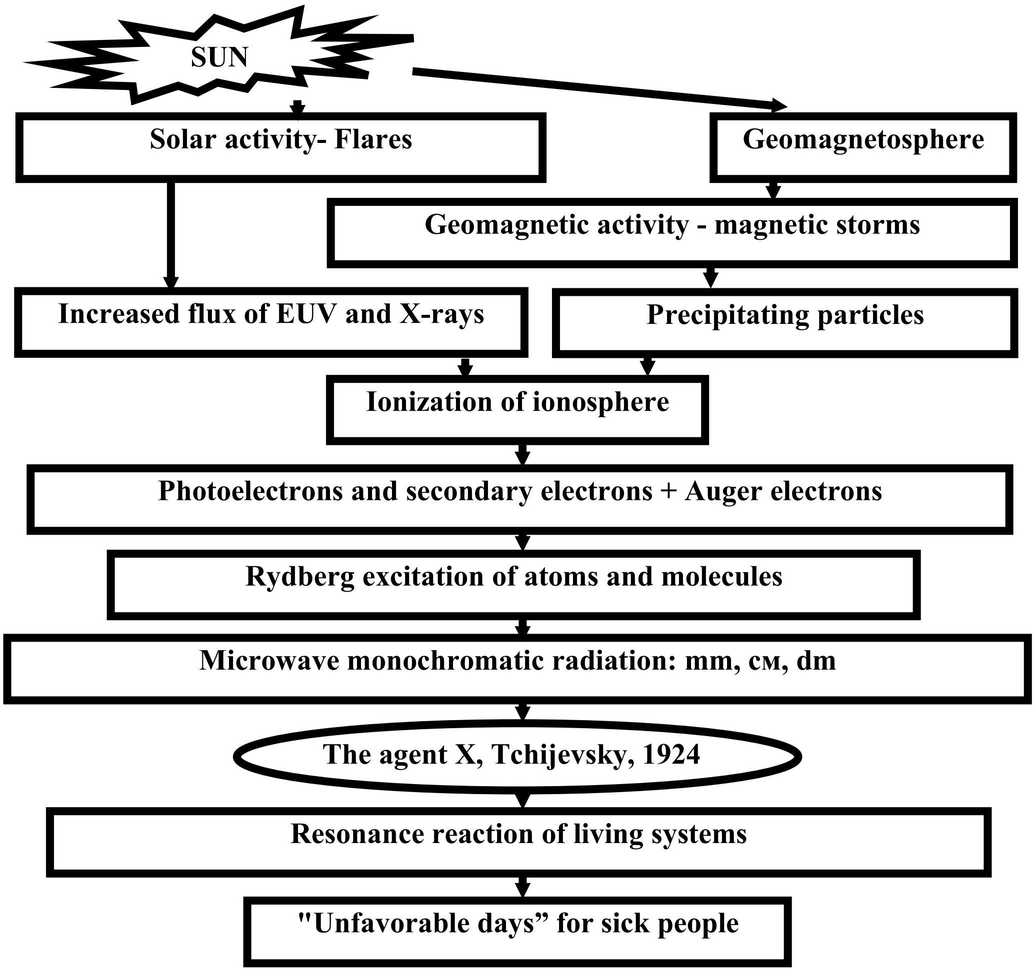

Fig. 2. Biological effects of solar activity and Rydberg states.

There are numerous experimental confirmations that microwave radiation has a biological effect. From the aggregate of such studies, it is possible to expect uniquely low levels of threshold action, all the way to 10^{-15} W cm^{-2}, which is close to the thresholds of perception of vision and hearing [46]. There is an extremely nontrivial effect for the case of a geomagnetic storm, and taking this into account can fundamentally alter the technique and treatment of numerous experiments on magnetobiology. Actually, unlike the standard understanding of the changes of the geomagnetic field during a storm (with a maximum at the centre of the chief phase), the precipitation of particles from the radiation belts that accompany these changes experience sharp attenuations (to the recording threshold in the course of 1.5–3 h) at the beginning and end of the chief phase. Only at the centre of the chief phase at middle latitudes in 2–4 h do they actually reach the maximum values – to the level of auroral precipitations [31].

Thus, the mapping of a biophysical experiment on magnetobiology to the values of the generally used indices of geomagnetic activity that semi-quantitatively describe the variation of the Earth's magnetic field (K_p, A_p, or D_{st}), as it is usually done, does not perfectly reflect the intensity of the corpuscular irruptions into the ionosphere in the period of a magnetic storm and hence does not correspond to the intensity level of sporadic microwave radiation of the ionosphere. This may be associated with the appearance of null results when modelling the conditions of a magnetic storm in laboratory experiments on biological objects. The papers [6, 7] showed that it is the microwave radiation of the ionosphere that must play the main role in the biospheric effect of a magnetic storm. It is important that the radiation signal of the ionosphere exceeded the intensity of the RF flux from the quiet Sun by a factor of 2–40 (at the wavelength of λ=50 cm), where the latter equals (4–6) 10^{-21} W cm^{-2} m^{-1} ([31], p. 13). The width of the surge reached 1 GHz. The flux of ionospheric microwave radiation of the ionosphere at λ=50 cm in the period of a solar flare is then (according to the data of the measurements of [43]) (3–70) 10^{-16} W cm^{-2}.

The ratio of the energies dissipated in the ionosphere when there is a medium solar flare and during a geomagnetic storm shows that the flux of microwave radiation can be by the factor of 10–100 greater in intensity in the period of a magnetic storm. In this case, the radiation in the centimetre and decimetre ranges can now exceed 10^{-11} – 10^{-12} W cm^{-2}. On the other hand, a calculation of the excitation rates of the Rydberg states of the oxygen atom [51] gave a value of about 10^9 particles cm^{-2} sec^{-1} in a column of the ionosphere during the period of a medium class-2B solar flare. Then, for values of the quantum energy in the centimetre range of $2{\cdot}10^{-23}$ (for λ=1 cm) – $2{\cdot}10^{-24}$ J (for λ=10 cm) in this column in ten allowed transitions, we have a flux density of microwave radiation of $2{\cdot}10^{-13}$ – $2{\cdot}10^{-14}$ W cm^{-2}. This flux density is the lower limit for transitions with Δn=1 (only for Δl=1), i.e., those of the type n', l'=n'-1 > n'-1, l'=n'-2, where n'=11–20 for an oxygen atom. This value increases to 10^{-11} – 10^{-12} W cm^{-2} during a magnetic storm. Because the densities of oxygen atoms and nitrogen molecules are nearly equal at the altitude of about 200 km, where, according to [51], there is a maximum of the altitude profiles of the Rydberg excitation rates, and recalling the identical character of the allowed radiative transitions in highly excited (hydrogen-like) atoms and diatomic molecules, it should be expected that the total flux of sporadic RF radiation, taking into account the nitrogen molecules, is approximately doubled.

Our energy estimates, without claiming to be complete, show that the experimentally observed sporadic RF radiation of the ionosphere in the period of solar flares and geomagnetic storms is well explained by the energetic of the allowed microwave transitions from the Rydberg excited states of the main gases of the upper atmosphere at altitudes of about 200 km - the oxygen atom and the nitrogen molecule. Thus, the resulting energies of the microwave radiation flux of the ionosphere make it possible to regard this radiation as the main agent in heliogeobiocorrelation effects. According to [6, 7], the microwave radiation itself mainly provides the energy component of the effect, and its modulation by low-frequency oscillations of the electromagnetic and infrasound geomagnetic fields provides the information component. Laboratory experiments in which modulated microwave radiation acts on biological objects show that it is substantially stronger than microwaves with constant intensity. The effect of modulation is most pronounced at lower intensity levels of the microwave flux and also depends on the initial state of the biological system. It follows from what has been said that it is necessary to provide constant monitoring of the intensity and spectrum of the microwave radiation of the Earth's ionosphere, not only in terms of a methodological improvement of biophysical experiments under conditions of elevated solar and especially geomagnetic activity but also possibly for recording the level of "unfavorability" of the heliogeophysical situation. The medical and biological mechanisms of this problem should be considered, taking into account the phenomenon of stochastic resonance [46], where the background microwave radiation of the ionosphere (before a storm and a flare) plays the role of the noise component. The same phenomenon can be significant in studies of the influence of microwave frequencies of cellular telephones. Here the role of the noise signal, which sharply increases in the period of solar flares and magnetic storms, will be played by the ionospheric microwave radiation. Since it is very variable, the possible resulting medical effect from cellular telephones and ionospheric sporadic radiations significantly varies in magnitude, and this creates indeterminacy when it is studied. The phenomenon of dissipative resonance can also be relevant to the study of these problems.

4. The radiooptical trigger mechanism in the problems "Sun - weather" and "Sun - climate"

Solar flares induce (usually in two days) geomagnetic storms which cause precipitations of charged particles mostly electrons from the radiation belts. Therefore there are two basic factors which affect the ionosphere during the increase in the solar-geomagnetic activity: these are extreme ultraviolet and X-ray radiations of the Sun and electron precipitations. They both carry large energy and their intensities vary strongly. These factors mainly determine the energetic level of solar geomagnetic activities but neither electromagnetic radiation nor corpuscular fluxes penetrate down to the low troposphere: they do not reach the troposphere, being absorbed at much higher altitudes [13]. Therefore as we know that solar flares and geomagnetic storms affect the weather, there must be a physical mechanism by which the energy of EUV/X-ray radiation as well as electron energy are transferred from the ionosphere down to the troposphere. Till recently no relevant mechanism was known [13].

We have proposed a new factor by means of which both solar flares and geomagnetic storms affect weather and climate characteristics. This factor is the microwave emission of the upper atmosphere and ionosphere [51]. Microwave radiation from ionosphere during solar flares and geomagnetic storms as well as microwave bursts from the Sun is supposed to control the condensation processes in the low atmosphere and thus affect the weather. This physical mechanism is based on taking into account the excitation of Rydberg states of atoms and molecules in generation of the ionospheric microwave radiation and in realization of the dissociative recombination of cluster ions in troposphere [56]. The tropospheric Rydberg atoms (molecules) recently [57] were drawn for explanation of cohesion of ball lightning.

It is shown that intensity of the ionosphere microwave radiation determines the rates of both association and dissociation of cluster ions [8, 9]. These ions generated from the water vapour and probably carbon dioxide in the low atmosphere at the altitudes exposed both to galactic cosmic rays - GCR and solar cosmic rays – SCR. We have taken into account that during the course of high-mountain observations [58, 59] it was found that atmosphere transparency as well as some other weather characteristics correlate with the solar microwave bursts. On the basis of observations these papers suggested the influence of solar microwave bursts on the water vapour state and on the condensation processes in the low atmosphere. It has been shown that due to this influence the water vapour clusters are formed and as a result the cluster absorption bands appear and depend in the spectral range of 320-350, 360, 380-390, 400 and 480 nm. Also the spectral optical thickness of the atmosphere decreases in the visible and IR range.

It was found in [59] that microwave radiation of the Sun influences dynamical equilibrium in distribution of the lower atmosphere clusters toward extent of water vapour association (it can both increase and decrease the association extent). This is important when we take into account the condensation mechanism, which, according to [59], dominates in the solar-weather link. It was shown in [60] that ions, generated in the atmosphere due to high-energy SCR, can condensate water vapour and cause change in the altitude temperature profile of the lower atmosphere (this change was registered experimentally). These phenomena, resulting in the hearth change of altitude of isobaric surfaces, cause additional vertical and horizontal gradients of pressure. The results obtained in [60] are important, because they might be considered as a confirmation of the non-linear mechanism of the solar activity influence on the meteoparameters of the troposphere. This mechanism can transform relatively a weak effect of SCR (less than 0.1% of the solar constant) to the 10% decrease in the total energy income to the troposphere. Results of [60] were obtained by means of approaches developed in [61, 62].

In troposphere the ionization caused by GCR plays the main role in the condensation process. The dissociative recombination of the water vapour cluster ions in an ambient molecular gas is the main channel of decay for these ions. The calculations of the coefficients of reactions of three-particle electron-ion recombination were performed by the author of [63], who interpreted results of the laboratory experiments with the ions $(CO_2^+)_n$ and $H_2O^+(H_2O)_n$. It was suggested the theory of this mechanism which includes two stages:

– collisions between electrons and gas molecules (nitrogen and oxygen molecules in case of condensation mechanism) fill Rydberg levels,

– electrons from the Rydberg states take part in non-radiative transitions resulted in dissociation of clusters.

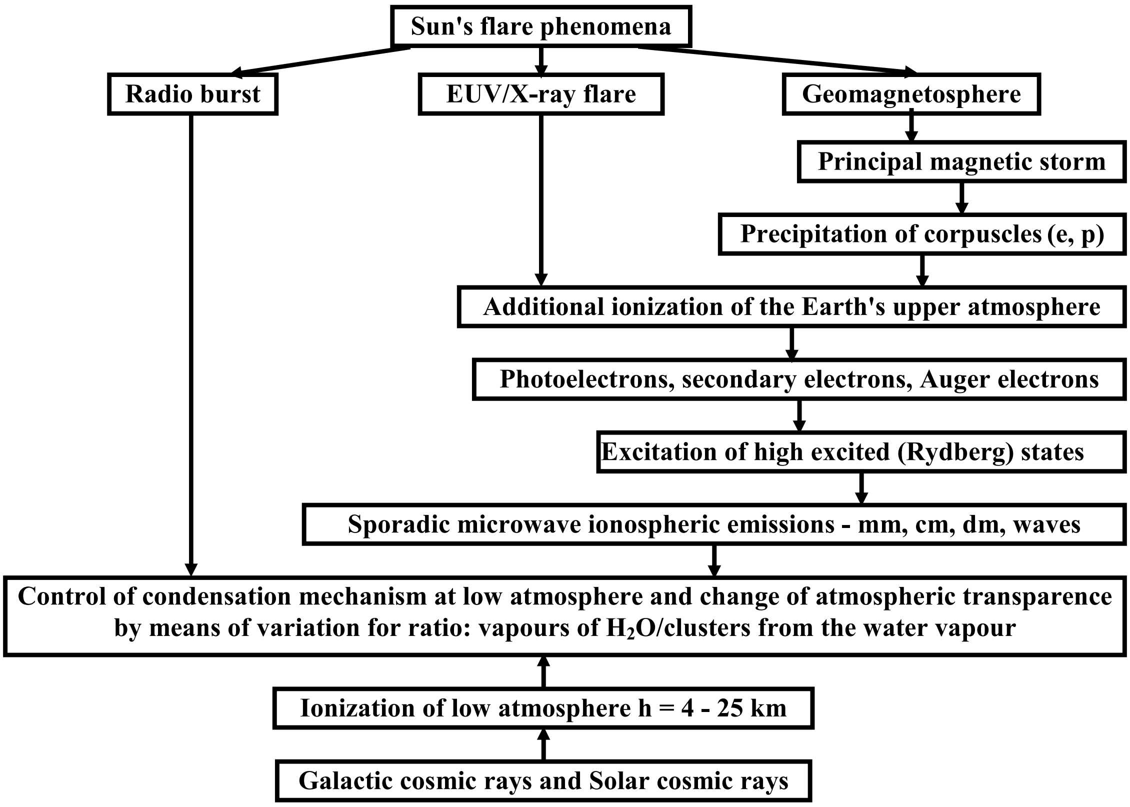

Fig. 3a. The diagram of control condensation mechanism induced by disturbances in solar and geomagnetic activities.

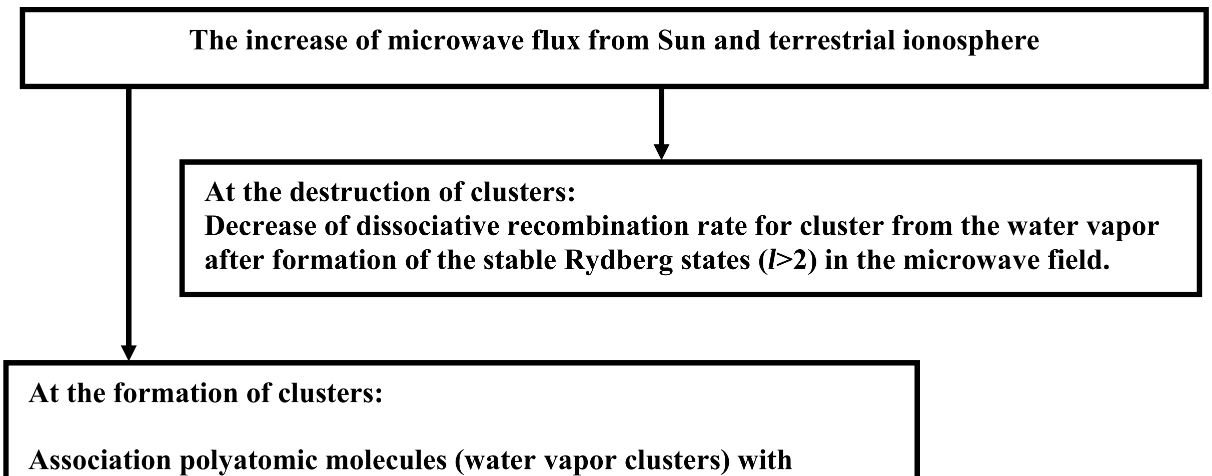

Fig. 3b. Control of condensation mechanism at low atmosphere and change of atmopheric transparency by means of variation for ratio: vapours of H_2O/clusters from the water vapor.

In [63] it was proposed to call this process as the “collisional dissociative recombination”. The process is effective for large proton hydrates $H_3O^+ (H_2O)_n$ over the wide range of pressure of ambient gas including altitudes of the lower atmosphere. In that case the following scheme of influence of the solar microwave radiation on the concentration of the ion clusters of water vapour and, probably, carbon dioxide could be proposed, Fig. 3 [8, 9]. According to [63] co-efficients of the rate of dissociation of the ion clusters of water vapour and carbon dioxide molecules are sharply dependent on the mean value of change in the orbital quantum moment (l) of the Rydberg level occurring as a result of collision. Probability of dissociation increases for small values l while for large values l it is low. Therefore, at time of the solar radiobursts and sporadic increases of the microwave Rydberg radiation of ionosphere (they occur during solar EUV and X-ray flares and geomagnetic storms), Rydberg levels with higher l will be filled due to processes of "collisional dissociative recombination" induced by the absorption of increased flux of the microwave radiation. This would result in decrease of the probability of dissociation of the cluster ions in the lower atmosphere. Thus, the present work proposes for microwave radiation to play a new role in processes in the lower atmosphere: according to the obtained results it can influence probability of dissociation of the water vapour and, possibly, carbon dioxide cluster ions by means of the mechanism of "collisional dissociative recombination" of high values of the orbital quantum numbers of the states of Rydberg electrons (they occur as a result of absorption of quanta of microwave radiation of the Sun and ionosphere).

It was experimentally observed in [58, 59] that radio emission can cause both generation and decay of water clusters in the lower atmosphere. Therefore, we can have the mechanism of influence by microwave radiation on the cloudness and may be on the precipitations such as in [64]. Decline in the water vapour abundance (its association into clusters) is observed as a result of burst of radio emission of the Sun at 2-5 cm while decay of clusters takes place when length of radio wave is 3-10 cm. These wavelengths correspond to Rydberg transitions in atmospheric gases with the principle quantum number n ~ 10. Water vapour can associate into clusters in framework of the scheme of generation of polyatomic Rydberg molecules suggested in [65]. Complex ions, originated in this process, are neutralized by capture of electron to the Rydberg orbital. Induced transition of the Rydberg electron due to microwave radiation also might play a role in this act. According to [43] flux of the ionospheric microwave radiation during solar flare is stronger than the corresponding flux during usual microwave burst at the Sun (typically they are separated in time for 10-15 min or more [31]). This testifies that a microwave radiation of ionosphere, generated as a result of absorption of X-ray and EUV radiation of solar flare, might contribute to weather phenomena. Correlation of the extent of spectral attenuation in the soft UV band (likely connected with water clusters) with the Sun's activity, obtained in [59], is in a good agreement with our hypothesis because increase of activity causes rise in all kinds of microwave radiation (both from the Sun and from ionosphere) and decrease of cluster decay due to filling of high l levels.

Thus, we have founded the following scheme for the three-stage trigger mechanism in solar-atmospheric links:

1. Conversion of absorbed solar radiation as well as absorbed corpuscular fluxes precipitating from radiation belts and magnetosphere into microwave radiation which penetrates down to the Earth surface.

2. Governing the ratio of association rates to dissociation rates both for water cluster ions and for CO_2 cluster ions.

3. Cluster contribution to the formation of clouds and aerosol layers, which in turn determine both the magnitude of thermal radiation fluxes coming up from the underlying surface.

The role of clouds in the radiation budget of the earth-atmosphere system mainly depends on its optical thickness. So, optically-thin clouds at high and middle altitudes cause a net warming due to their relative transparency at short wavelengths but opacity in the IR region, whereas optically-thick clouds produce a net cooling due to the dominance of the increased albedo of short-wave solar radiation [66]. It was pointed out in [67] that cloudness decreased both the influx of shortwave solar radiation coming down to Earth surface and effective longwave radiation coming up from the surface. As a result the total radiation flux coming to Earth surface cloud increase in the radiation balance is negative (at the middle and high latitudes – in winter) and decrease when the balance is positive (in summer). Thus the growth of cloudness can lead to different affects in dependence on latitude, season and characteristics of the underlying surface. The response of atmospheric parameters (such as transparency, pressure, atmospheric circulation, etc.) to various factors of influence depends on the geographic parameters, first of all on latitude. The effects from various impacts are overlapping and observed as a total combination, the more so that changes atmosphere structure last during several hours [68].

We emphasize that all stages of the proposed mechanism are experimentally confirmed:

(i) the microwave ionospheric emission, which intensifies during solar and magnetic storms, was detected in [43-45];

(ii) the regulation of humidity at altitude higher than 3 km by the solar microwave emission and flares was registered in [58, 59];

(iii) a direct influence of solar flares and magnetic storms on the total cloudiness is distinctly registered [69-71].

(iv) optical emissions between the Rydberg sublevels of atomic oxygen were registered in [48] during mountain studies of the nightglow spectrum in the region of 394–927 nm.

The aforesaid made it possible to propose a new physical (radiooptical) mechanism of the effect of solar and geomagnetic activities on phenomena in the lower atmosphere, including the weather characteristics. This is the effect of the microwave ionospheric emission, the intensity of which in Rydberg transitions depends on the level of solar and geomagnetic disturbances of the ionosphere and is several ten times as high as the intensity of typical microwave solar bursts. If we take into account the three stage radiooptical trigger mechanism, we can understand why the eleven-year solar cycle does not affect the air temperature near the Earth surface. According to the trigger mechanism smoothing is caused by the action of precipitating charged particles which present the main factor of geomagnetic activity and which affect the intensity of microwave radiation. The main maximum of geomagnetic activity takes place three or four years later than the maximum of eleven-year cycle of solar activity. At the same time there is a weak maximum in magnetic storms distribution which occurs two or three years before solar activity maximum [31]. Thus due to these shifts during the eleven-year cycle the intensity of microwave radiation which controls the near-surface air temperature appears smoothed out [14].

5. Conclusion

The long-term studies of physics and optics of the upper atmosphere and ionosphere, along with the development of the optical–electronic equipment in order to register the spectrum and absolute fluxes of the solar ionizing radiation [15, 17, 39, 40], for the first time led to obtaining certain important results in the field of solar–terrestrial physics. The following results were obtained: (1) We constructed the entire energy spectra of ionospheric photoelectrons and secondary electrons based on the consideration of the Auger effect in physics of the ionosphere [3, 4, 31]; (2) We developed the optical–geophysical models of the UV, optical, and microwave emissions of the Earth’s ionosphere (using the total spectra of ionospheric electrons) for quiet conditions and periods of solar flares and magnetic storms [1]; (3) We detected a new geophysical phenomenon – the response of the night-time upper ionosphere to solar flares [25-27] – and constructed the optical–geophysical model of this response based on the consideration of a new main mechanism of production of two charge positive ions of atomic oxygen (double photoionization of neutral oxygen atom by one photon [5]). The performed work made it possible to propose a fundamentally new idea of the physical mechanism of solar–terrestrial links through the microwave ionospheric emission, originating when highly excited (Rydberg) states are excited during collision of high-energy ionospheric electrons with gas atoms and molecules in the upper atmosphere [1]. Transitions between these states with a principal quantum number of $n > 10$ are in the microwave range (in the range of wavelengths from several millimetres to decimetre and longer). Such a radioemission easily (except several absorption bands) penetrates into the troposphere and reaches the Earth’s surface. Consequently, precisely this emission can be the physical factor that affects the biosphere and several weather characteristics.

The most important problem of the up-to-date science is to understand the basic causes of global changes in environment. Elaboration of the mechanism of solar and geomagnetic activities influences on the low atmosphere is one of the most complicated problems of the solar-terrestrial physics [13]. For the practical purposes it is very important to understand what solar variability contributes to the global climate changes, including growth of the mean surface air temperature observed in XX century.

According to [72] the several past decades all the trends in the Sun that could have had an influence on the Earth's climate have been in the opposite direction to that required to explain the observed rise in global mean temperatures and therefore the observed rapid rise in global mean temperatures seen after 1985 cannot be ascribed to solar variability.

Indeed, since 1985 the total solar irradiance (TSI) and extreme ultraviolet and soft X-ray radiation (EUV/X-ray) ionizing fluxes have been decreasing, but geomagnetic activity (aa - index) has been going up till 2003 (+0.3 % / year). Only during the last few years (on November 2008) geomagnetic activity also started decreasing (- 6.7% / year) [73, 74]. This means that negative trends after 2003 have come both for solar and geomagnetic activities and according to our mechanism the natural global climate changes will go down to lower levels [73, 74].

During the last decades the influence of GCR and SCR on the cloudness has been studies in detail. Cosmic ray-induced ionization is the principal source of ionisation of the stratosphere and troposphere and can slightly modulate cloud formation. The long-term decline in GCR has fallen several ten years and this is reflected in the significantly lower peak at the solar maximum near 1990, than during the previous two solar maxima [75]. But after 1996 there is the increase both in last minimum of GCR (near 2000) and in maximum of the instant eleven-year solar cycle [76]. The factors of the cosmic rays influence are Forbush decrease of GCR and sporadic increase of SCR. However these events are rare. For instance, geomagnetic storms (with K_p more than 5) occur 20-80 times per year and solar flares (class greater than M5) take place approximately 50 times per year [77] whereas Forbush decrease of 3% and more occurs only 2-4 times per year and solar proton events at energy than 100 MeV take place approximately 5 times per year that is approximately ten times lesser. Therefore we developed a novel radiooptical trigger mechanism of the solar flares and geomagnetic storms influence on the weather and climate.

In [73, 74] it is shown in the present paper that during last years the main factors of solar variability influence on the weather and climate changes sign of trends in the direction that leads to the decrease in the global mean surface air temperature. According to the recent meteorological data [78, 79] the rate of global warming in 2008 appears to be slowing [80, 81].

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