Space solar patrol mission for monitoring of the extreme UV and X-ray radiation of the Sun

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Abstract. The paper describes our proposal to make the monitoring of the extreme UV and X-ray radiation of the Sun in the spectral range of 0.14 - 157 nm. It has been noticed that this spectral range strongly affects to solar--terrestrial relationships, especially at the periods of solar activity. But at present, solar ionizing radiation is constantly monitored only in two spectral intervals: below 0.8 nm and above 115 (119) nm. This happened because of methodological and technical difficulties, which dealt with the necessity to use detectors of windowless optics. Such "solar - blind" detectors – open secondary-electron multipliers (SEM) – has been produced by the S.I. Vavilov State Optical Institute (SOI), Russia. Nowadays, being used the SEM detectors, all Space Solar Patrol (SSP) instrumentation has been created and laboratory tested.

Introduction

In recent years there has been an increase of the interest in researches of the solar activity and its effects in phenomena on Earth. It is generally known that solar activity events cause of numerous phenomena in solar-terrestrial relations. Unfortunately, there has not been monitoring the flux in the most geoeffective region of the spectrum (0.8-119 nm) from the full disk of the Sun. At the same time there are difficulties at the creating of International Standard for solar irradiance below 120 nm [Avakyan, 2005]. The monitoring does not exist due to technical and methodological difficulties in performing of measurements and calibration in the given spectral range. They are connected, first of all, with absence of ionizing radiation detectors, which must be true "blind" to high-power visible light of the Sun. But the SOI, using the long-term experience, has developed such stable, low-noise, highly effective SEM with the photocathode of beryllium oxide, which have the falling of sensitivity to 200 nm by ten orders [Avakyan et al., 1998]. The development and construction of the SSP instrumentation, which used the SEM detectors, occurred from 1996 to 2003 [Avakyan, 2005; Avakyan et al., 1998]. This experiment has been built for permanent absolute measurements of the ionizing (extreme ultraviolet (EUV) and soft X-ray) radiation from the full disk of the Sun. Every 72 seconds a spectrum from 0.14 nm to 198 nm will be recorded with a resolution fewer than 1.0 nm. The SSP instrumentation consists of two radiometers and two grating spectrometers (an EUV-Spectrometer of normal incidence and a X-ray/EUV-Spectrometer of grazing incidence) [Avakyan, 2005; Avakyan et al., 1998; Afanas'ev et al., 2005a]. The permanent monitoring will allow carrying out accurate spectroradiometric measurements of ionizing radiation from solar flares, determining absolute EUV and soft X-ray radiations and predicting all cooperation of solar events related with flares [Avakyan et al., 2003].

Space Solar Patrol instrumentation

The permanent SSP apparatus consists of following units:

1. The radiometer of ionizing radiation for 0.14-157 nm spectral range, which ensures measurements of the absolute radiation flux of the Sun in 20 spectral intervals, allocated by filters made from thin metal foils, thin films and also optical crystals [Avakyan et al., 1998; Avakyan et al., 2003]. The use of several filters (from different substances) on overlapped ranges of wavelengths allows us to execute mutual calibration of channels of the radiometer in flight. There is also the control of sensitivity stability of the radiometer by X-ray radiation of isotope ^{55}Fe.
2. X-ray/EUV-spectrometer of the space patrol (spectrometer of grazing incidence), which measures the spectrum of radiation of the Sun in the wide range (1.8–198 nm) owing to the use of the unique optical scheme without an input slit, with diffraction grating with the variable ruling step [Avakyan et al., 2002]. The entire spectral range is divided into four overlapping sections by four measuring channels: two main (1.8 – 23 nm and 22 – 63.1 nm) and two experimental (62 – 122.7 nm and 119 – 198.1 nm). The long-wave experimental channel contains a photoelectric multiplier with a MgF_2 window (FEU-142) to control the diffraction grating's efficiency in flight and to calibrate the spectrometer with UV lamps in laboratory conditions.
3. EUV-spectrometer (spectrometer of normal incidence), which is intended for measurement of radiation fluxes from full disk of the Sun in the region of extreme ultraviolet radiation (16-153 nm) with the spectral resolution better than 1 nm by six channels [Avakyan et al., 2001a; Afanas'ev et al., 2005b]. Thus, two channels for range 16-57 nm are experimental (for experimental determination of measuring ability of spectrometer) and there is the auxiliary channel for the 195-230 nm spectral range to align the spectrometer under the conditions of the normal atmospheric pressure.

Open SEM with the "solar - blind" photocathode from beryllium oxide and 16 trough-shaped beryllium bronze dynodes is the unique development of the SOI and is used as detectors of the ionizing solar radiation in all measuring channels of SSP apparatus. Using special technological processing of the dynodes, a quantum efficiency of about 10% can be obtained in the working wavelength range with an abrupt efficiency drop by no less than five orders of magnitude at wavelengths longer than 150 nm.

Now devices of SSP apparatus have passed laboratory calibration tests by UV and X-ray sources of radiation both in vacuum chambers of the SOI, and ESTEC (for radiometer) [Avakyan et al., 2001b, Avakyan et al., 1999].

Methodology of the Space Solar Patrol

The methodology of patrol measurements consists of simultaneous use both extreme ultraviolet (EUV) and X-ray/EUV spectrometers and two identical radiometers, and also in application of the special algorithm of detection of signals both radiation and charged particles from radiation belts. So, the spectrometers measure a detailed source function and its variations, whereas the radiometer

directed to the Sun give reference information to obtain absolute intensity of a solar radiation flux. The optical axis of the second radiometer lies at angle of 10-15^0 to that of the first radiometer, i.e. it does not track the Sun. It will allow to take into account the signals from the charged particle fluxes, which are detected by both radiometers at nearly the same pitch angles. So, the information about background of charge particles can be estimated, and as a result, the correct absolute measurements excluding the scattered light in the spectrometer can be obtained.

It should be noticed that all spectral ranges of channels in the SSP instrumentation (both the spectrometers and radiometers) are overlapped. So, the necessary methodological duplication of measurements is provided; thus, in spectrometers all spectral intervals of channels are overlapped in the most intensive and important lines of the solar spectrum.

Moreover, several channels of the SSP apparatus have been provided with monitoring of the stability of its absolute spectral sensitivity. Besides this, there is the plan (#2500 project of the International Science and Technology Center, executed together with the Budker Institute of Nuclear Physics, Novosibirsk, Russia [Nikolenko et al., 2004]) to carry out the absolute spectral calibration of the SSP instrumentation 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 to check the variation in the pre-flight calibration at this wavelength after launching. An additional possibility is 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 wavelengths above 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 [Avakyan et al., 2003]. Finally, both of the spectrometers have auxiliary long-wave channels contained the FEU-142 photoelectric multiplier to measure radiation in the spectral region where the magnitude of variations in solar radiation fluxes does not exceed several percents during the eleven-year activity cycle and the 27-day period of rotation of the Sun. Therefore, these channels enable monitoring the stability of the diffraction grating's efficiency at the periods without solar flares. There were not found any effects of influence of space factors on working a FEU-142 photomultiplier at low orbits [Avakyan, 2005]. Lastly, with due account of the present success achieved 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 data to these as well.

Conclusion

Till present there is no permanent monitoring of the short wavelength activity of the Sun in the most geoeffective spectral range (0.8 – 119 nm) due to methodological and technical difficulties with operation of detectors of windowless optics under space conditions. Due to use of the open secondary-electron multipliers we have overcome these difficulties and offer the Space Solar Patrol (SSP) instrumentation for monitoring of the extreme UV and X-ray radiation of the Sun. Now the SSP apparatus is completed and tested at the vacuum chambers of the S.I. Vavilov SOI and ESTEC (only radiometer). Within the frame new #2500 ISTC project the absolute calibration will be performed with high radiometric accuracy of all SSP instrumentation at the synchrotron radiation source. There are plans to launch of the SSP Mission at the Russian Module of the International Space Station for experimental operation (Radiometer and EUV-spectrometer) by the Rocket-Space Corporation "Energia" (Contract with Russian Space Agency). For permanent monitoring in the uninterrupted mode the SSP is also proposed to be installed on a satellite with solar synchronic orbit. So, the SSP mission for monitoring of the extreme UV and X-ray radiation of the Sun is a complete solution of the problem of the permanent patrol of ionizing radiation from the full disk of the Sun.

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