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Chapter 13

FIRST ROCKET EXPERIMENTS FOR RESEARCH ON SOLAR SHORTWAVE RADIATION*

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On 15 August 1951, for the first time in the Soviet Union, scientific equipment was lifted on board a rocket to an altitude of around 100 km in order to study the spectral composition of solar shortwave radiation.

The opportunities for spectroscopic research on celestial bodies on the ground are substantially limited by the absorbing action of the terrestrial atmosphere. Located on the Earth, we can observe the universe surrounding us only via two relatively narrow spectral ranges of atmospheric transmittance. The first encompasses the so-called visible range and the nearby sections of the ultraviolet [UV] and infrared [IR] ranges and the nearby sections of approximately 3,000 Å to 14 μ (with a non-transmittance range of from 2.5 to 8 μ). Astronomers conduct their observations through this "window". The second "window" lies in the range of from several centimeters to several meters. Radio astronomers use this band of electromagnetic radiation. Thanks to the electromagnetic radiation coming to the Earth, scientists have available basic data about the composition and structure, temperature, pressure and other parameters of the external envelopes of the Sun and the stars, of a planet's atmosphere, of the nebulae and other celestial bodies, as well as of the upper layers of the Earth's atmosphere.

The fact of absorption of the UV section of the spectrum with long waves shorter than 3,000 Å was even noted by scientists nearly 100 years ago and, in 1880 Hartry ascribed it in accordance with the coincidence of the absorption bands to the ozone. Subsequent research on board rockets and satellites confirmed this and indicated that the absorption of the UV section of the solar spectrum shorter than 3,000 Å is basically associated with the ozone which forms a quite narrow layer in the atmosphere, the maximum of which is located at an altitude of around 30 km.

In the range of long waves shorter than 1,800 Å and right down to 800 Å, the absorption is determined by molecular oxygen and in the even shorter-wave range of the spectrum -- by atomic oxygen and molecular nitrogen. Water vapor intensive-

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ly absorbs UV radiation; however, its content quickly diminishes with the altitude, becoming dissipatingly small at altitudes exceeding 30 km. In the IR range of the spectrum, the absorption is produced first of all by water vapor, then by carbon dioxide and only after this by molecular oxygen. Finally, in the radiowave range, the absorption is associated with the ionosphere, which usually makes the long-wave range greater than 30 m inaccessible for observation. In the submillimetric band, the molecular absorption becomes substantial, particularly that associated with water vapor and carbon dioxide gas.

Beginning in the middle of the 1930's, scientists made attempts to expand the observation range and in particular to investigate the solar shortwave radiation from high mountains and aerostats. However, these attempts were unsuccessful, inasmuch as the shortwave radiation does not descend to the heights attainable using stratostats and aircraft [1]. The first attempts at experimental detection of solar shortwave radiation using the new technical means -- rockets -- date back to 1943. In Germany, Kiepenhäuer and Regener prepared a spectrograph to be sent up on the V2 rockets; however, the experiment was not carried out.

In the Soviet Union, on the initiative of Academician S.I. Vavilov in 1947-48, in the State Optics Institute (SOI), A.V. Yakovleva and in 1950-51, in the USSR Academy of Sciences' Physics Institute P.N. Lebedev and S.L. Mandelshtam began work on developing equipment for research on board rockets of the spectral composition of the UV and x-ray sections of the solar radiation and the absorption capabilities of the ozone at altitudes of 55-60 km [2]. Similar research was begun in the U.S.A. in 1946-47. At the end of the 1940's, American scientists, using captured V2 rockets, obtained the first spectrograms of the solar shortwave radiation. In the first operation of the USSR and U.S.A., they used spectrographs with photographic recording of the spectrum and small resolution (in the USSR with quartz optics, in the U.S.A. with a diffractional lattice). In the American spectrograph, R. Tousey and his associates, instead of a slit, used the image of the Sun with a diameter of 0.03 mm, obtained from the ball from the LiF, and in the experiments by Hopfield and Clearman, a spectrograph was used with two slits, and in order to increase the field of vision, opaque plates, illuminated by lighting, were placed in front of the slits [2].

The first research in the USSR was carried out on the V1B geophysical rocket. It was developed based on the R1 ballistic missile with certain changes in the design of its tail and nose sections, as well as a guidance system for ensuring the vertical trajectory of the flight. In addition, for the first time, a system for recovery of the nose section was developed. The latter consisted of an instrument compartment with the spectrographs for investigation of the solar UV radiation (2,170-3,000 Å), a sealed compartment for experimental animals and a compartment for the recovery system with a parachute container and braking shields [3].

The first launch of the V1B rocket (with the SOI spectrographs) took place on 15 August 1951. The rocket soared upwards carrying with it a nose container with scientific equipment and experimental animals weighing on the order of 590 kg. The flight trajectory was nearly vertical. In the ascending section of the trajectory after the engine ceased operating, when the rocket was moving by inertia, for 188 sec, which corresponded to an altitude of 100 to 110 km, on command from the program device, the nose section separated from the body of the rocket.

Upon the transmission of the current impulse to the explosive bolts, the bonding links connecting the nose section with the body of the rocket separated. The separation was accomplished using six spring pushers which imparted to it an additional velocity -- of 0.6 m/s, in order to preclude the nose section colliding with the rocket body during the descending branch of the trajectory. Then there was a subsequent catapulting of the first (at an altitude of 75-90 km) and second (at an altitude of 75-85 km) carts containing the animals. At the same time, the braking shields were deployed with the aid of springs at a 60 deg angle and in accordance with the degree of entry into the dense layers of the atmosphere, first stabilized the nose section and then slowed it down to a speed of 140 m/s. At an altitude of 6-8 km, the lid of the parachute container shot off. The pilot parachute activated the drag parachute (with an area of 3.5 m^2) and the main parachute (with an area of 400 m^2) [4].

The spectrographs prepared for flight photographed the Sun on the ascending branch of the trajectory until the ceiling was reached. The main experimental difficulty was ensuring that the Sun would fall into the field of vision of the spectrograph for an adequate amount of time during the rotation and tip-over of the rocket in the passive section of the trajectory. In connection with this, the SOI spectrographs were equipped with an illuminator with an angle of vision of 120 deg and three instruments were installed in the nose section, which covered the entire field of vision.

The recovery system operated so well that it was possible to use the instruments for a number of flights. Three launches were made on the V1B and 56 spectrograms were obtained which were suitable for processing, of which 22 were beyond the limits of the ozone absorption layer. A recording was made of the section of the spectrum from 4,000 Å to 2,300 Å. Using the quartz spectrograph, a series of spectrograms were obtained, according to which the displacement of the boundary with the altitude, caused by the absorption of the ozone, which extends in the atmosphere right up to 55 km, is traceable. In the entire range of the spectrum obtained on these photos, its nature remained the same as that of the intensive continuous spectrum with numerous lines of absorption in the $\lambda \sim 3,000$ Å range previously observed from the Earth. Particularly intensive and broad were the lines Mg II $\lambda \sim 2,802.7$ and $\lambda \sim 2,795.5$ Å (corresponding H and K to the lines of Ca II), observed from the Earth. The obtained spectrograms had a resolution of up to 1 Å. In the section of 2,250-2,881 Å, nearly 300 Fraunhofer lines were recorded [5].

In order to investigate the upper layers of the terrestrial atmosphere and basically the ozone layer, scientific equipment was sent up on the MR-1 meteorological rockets in the USSR. In the SOI, special spectrographs had been developed with circular coverage illuminators, for the spectrum range from 4,000 to 2,000 Å. The use of fluorite optics in them in combination with a mirror-like objective made it possible to obtain a plane focal surface and to place the spectrum on the generated cylinder using a drum-type cassette. At the same time, the amount of time required to change the exposure was all of 0.1 sec. The photographing was done with a set of exposures ranging from 0.07 to 4 sec.

All the equipment was tested on CAO [Central Aerological Observatory] stratostats, sent up to altitudes of 20 km, before being launched on the V1B and MR-1 rockets. These tests made it possible to discover and eliminate certain design shortcomings in the instruments, but the altitude was inadequate for observation of the ozone layer. The first launch on an MR-1 rocket was accomplished on 19 July 1955, with the Sun at an altitude of 14 deg 15 min. Thirty result-yielding spectrograms with an exposure of 4 sec were obtained using a second version of the illuminator. The last spectrum was obtained at an altitude of 75 km. In order to calculate the ozone concentration, the method of the relative intensity of two long waves was used. At the same time, on the day the spectrograph was launched and during the very same hours, ground observations were made of the ozone layer according to the scattered radiation from the zenith [6].

During this same period, an evaluation was made of the solar radiation stream in the UV range without spectral analysis using the thermoluminescent phosphors $SaSO_4(M4)$ developed in the SOI by V.A. Arkhangelskaya and photon counters.

The phosphor $CaSO_4(Mn)$ possesses extremely valuable qualities, making it possible to use it to produce absolute radiation measurements in the shortwave range of the spectrum of 1-1,300 Å. The described instrument was used during the total solar eclipse of 15 February 1961 to measure the solar x-ray radiation. The instrument was installed on an R2A rocket and it operated at altitudes of from 60 to 96 km. During the measurements, the instrument was aimed at the Sun with an accuracy of ±1 deg. After every 22 seconds there was a change of the plates with the phosphor. In all, six measurements (of the total amount of light) were obtained, five of which were related to the moment of totality of the eclipse. The results of the measurements indicated that the recorded light sum decreases with the decrease in the altitude of exposure of the phosphor and the maximum light sum corresponds to the trajectory peak [7].

Further successes in the investigation of the solar UV radiation were due to the use of the servo systems in the rocket experiments, which ensured control of the spectrographs and other instruments over the course of a significant section of the rocket's flight.

The original design of the rocket spectrometer with photoelectric recording of the spectrum in the 20-1,300 Å range was developed by the SOI and FIAN [The Academy of Sciences' Physics Institute], in 1956. In this instrument, in order to increase the aperture ratio, a plane diffraction lattice and (Soller) collimators for collimation of the incoming and outgoing beams were used. An open-type VEU [Reiterative Electron Multiplier] was used as the receiver. The instrument was combined with the servo system [2].

In 1955-56, a new model solar spectrograph with a diffraction lattice with a 1-meter curvature radius was installed on an updated V1Ye rocket. The spectrograph was placed on the very tip of the nose of the rocket and was equipped with a homing head. Azimuth tracking was accomplished by rotation of the entire head, and altitude tracking by oscillation of the plane mirror, with a 60 deg angle of view. The modification of the V1Ye distinguished it from the preceding V1B by the presence of special powder accelerators, with whose aid the nose section moved away from the rocket at the trajectory peak. This solar spectrograph, the spectrum from 3,000 to 2,470 Å with an inverse dispersion of 16.7 Å/mm and a resolution of 0.3 Å was recorded.

In 1957, the new V2A geophysical rocket was developed for research up to 200 km. The rocket had a separable and recoverable nose section weighing 2,200 kg. On 13 August 1957, the first experiment on the investigation of the solar UV radiation took place on the V2A rocket using the SOI spectrograph. Later there followed launches in 1958, 1959 and 1960. In these experiments, solar spectrograms from 3,000 to 2,080 Å with an inverse dispersion of 16.7 Å/mm were obtained for the individual sections, and in 1959, ones were obtained with an inverse dispersion of 8.3 Å/mm and a resolution of 0.15 Å. As a result of this research, bismuth with an abundance corresponding to its prevalence in space was discovered on the Sun. A detailed study of the resonance lines of Mg II at 2,800 Å indicated that, on the broad absorption lines with wings encompassing nearly 200 Å, sharp emission lines were superimposed, which in turn were self-inverted. The intensities of the lines of the components of the doublet were as indicated in Table 1 and, apparently, do not depend on the activity of the Sun [8].

Table 1

INTENSITIES OF LINES OF COMPONENTS OF THE DOUBLET

Date of Photographs	Time	(Units of microwatts)/cm²		Spectral Resolution	
		2,975	2,802		
31 May, 1956	2 h 57 m	1.05	0.76	0.3	2,016
10 July, 1959	4 h 47 m	1.06	0.72	0.15	1,570
15 June, 1960	3 h 22 m	1.02	0.79	0.4	1,513

The distribution of energy on the solar UV radiation for the range of 3,000-2,470 Å was measured by comparison with the radiation of a crater of a carbon arc and a krypton lamp. The data obtained according to the spectrograms with a resolution of 0.3 and 0.4 Å agree with the photometric curves obtained by the American authors. The results of the measurements according to the spectrograms with a resolution of 0.15 Å agree with them only in the sections up to 2,870 Å, and for the shorter-wave range there is a notable divergence, amounting to 60 percent at 2,700 Å. This divergence, evidently, must be attributed to the discrepancy between the programmed exposure and the actual exposure, which resulted from the fact that they still remained exposed while radiation that fell through the slit of the spectrograph did not illuminate the lattice but could cause flashes within the instrument that distorted the density of the film.

Although the brightness of the continuous spectrum in the UV range, because of the abundance of absorption lines, was lower than in the visible range and corresponded to the effective brightness temperature ~4,800°K, within the spectrum, several sections were discovered with a brightness temperature exceeding 6,000°K, for example, for sections $\lambda = 2{,}913$ and $\lambda = 2{,}917$ Å $T \approx 6$, 200°K.

Beginning with 1958, this research was continued on even more powerful V5A rockets with a lift altitude of more than 500 km and stabilized in the passive section on all 3 axes with an accuracy of ±3 deg using gas jet nozzles. The new type of geophysical rocket made it possible to substantially increase the duration of the measurements. An attempt was made on these rockets to record the solar radiation in the range of the hydrogen line 1,215.68 Å, using the same spectrographs with a metric diffraction lattice, however, the exposure turned out to be inadequate and the spectrum was obtained with a strong underexposure and broke off at 2,080 Å [6,8].

At an altitude of nearly 200 km on the descending section of the trajectory, the nose section of the V5A rocket separated, turned at an angle of 90 deg relative to the direction of the flight and moved away in order to avoid the possibility of a collision with the rocket body. At an altitude of 4-5 km, the recovery system worked perfectly and the nose section landed by parachute [3].

In 1958, in order to investigate the composition of the atmosphere and the solar UV and x-ray radiation, the small R2A geophysical rocket was developed with a high-altitude automatic geophysical station (HAAGS) with a diameter of 1 m and weighting 400 kg [3].

In 1959, FIAN equipment was sent up twice on these rockets to an altitude of around 100 km. In the experiments, for the first time, the equipment was homed in on the Sun. The counters were placed outside the instrument container, which, after the passage through the dense layers of the atmosphere, separated from the rocket and oriented itself in space according to three axes, aiming the instruments at the Sun and maintaining its orientation in the ascending and descending sections of the trajectory with an accuracy of ±0.5 deg.

On 21 July 1959, the intensity of the x-ray radiation in the range of 2-10 Å was measured on an R2A rocket during a launch to an altitude of around 105 km. The Sun was located close to the horizon; therefore, the x-ray radiation passed through a large layer of the atmosphere and began to be recorded only at an altitude of around 90 km. Right next to the operational counter was a control counter turned away from the direction towards the Sun by 15 deg. The counting speed of this counter was on the level of the cosmic background and this indicated that the radiation recorded by the operational counter actually did come from the Sun. These measurements indicated for the first time that it was possible to have on the Sun an active region with a temperature of $\sim 4.10^6$ °K [2].

The close connection uncovered between the solar x-ray radiation stream and the active regions on the Sun led to the setting up of special experiments to investigate the regions of primary x-ray radiation generation in the solar corona. The direct experiments were performed during the total solar eclipse of 15 February

1961. In order to do this, a rocket with photon counters was launched in the zone of the total eclipse during the time of its development.

At the same time, radiation ≤ 10 Å was measured coming from the "hottest" regions of the corona. The time of the launch and the trajectory were chosen so that the highest point of the trajectory (around 96 km) would be approximately on the axis of the shadow cone. At this moment, the entire transition region between the chromosphere and the corona and the innermost part of the corona were covered by the Moon and the only exposed areas were two active regions on the western and eastern edges of the disc. The radiation stream decreased in comparison to the average value of the stream for the completely exposed Sun, however, maintaining a notable value of 8.10^{-5} ergs/cm^3 sec. This was proof of the fact that the x-ray radiation generation occurs in the solar corona and primarily in the regions of the corona located above the active regions in the chromosphere. This yields an immediate interpretation of numerous ionospheric observations during an eclipse, from which the primary role of the corona's active regions in the formation of the E layer becomes apparent [2].

In 1962, in order to have more qualitative research on the upper atmosphere and the shortwave solar radiation, a new nose section was developed for the V5B rocket -- the HAAGS; and on 6 and 18 June 1963, on the HAAGS, I.V. Katyushina carried out the first experiments on measuring the intensity of the direct solar radiation at altitudes of 80-500 km using the ionization chamber to measure the solar radiation in the Lyman-alpha hydrogen line. On 6 June, 25 October, and 25 December 1963, using counters for UV scattered radiation, measurements were made of the intensity in the lines of the atomic oxygen triplet $\lambda \sim 1{,}300$ Å at altitudes of 100-500 km.

The instruments were installed in the spherical container of the HAAGS, equipped with a stabilization and attitude determination system; thus during the stabilized flight of the container, the instruments were aimed at the Sun.

As a result of these experiments, a measurement was made of the distribution of the intensity of Lα radiation with altitude; and, as consequence, there was a determination of the absorption coefficient of Lα radiation at altitudes of 80-90 km and the concentration of molecular oxygen. The experiments indicated that the intensity of solar Lα radiation beyond the limits of the atmosphere amounted to 4.5-8.9 ergs/cm^3 sec, and the intensity of the scattered radiation at the maximum amounted to 0.62; 0.91 and 0.05 kR for the experiments of 6 June, 25 October, and 24 December, respectively.

The experiments conducted on the V5B rockets made it possible to draw the conclusions that the maximum intensity of the scattered radiation in the 01 triplet line increases at the zenith angle of the Sun decreases and the maximum of the intensity is shifted at the same time into the region of the lesser altitudes [9].

Later, in several experiments on the rockets, the direct photographing of the solar disc was accomplished in the soft x-ray region of the spectrum. In particular, on 1 October 1965, a photograph of the Sun was obtained in the 170-200 Å range.

In this and in other experiments, the Sun was photographed using several cameras obscured with apertures covered by filters made of beryllium and aluminum foil and organic film, separating the individual sections of the spectrum. The cameras were located in the recoverable instrument compartments of the geophysical rockets, which climbed to an altitude of 500 km. During the flight, the cameras were aimed at the Sun using the servo system with an accuracy of ±30 min. in the ascending and descending sections. The equipment descended to the ground by parachute. An analysis of the obtained photographs indicated that the x-ray radiation was generated primarily in the corona's active regions, located above the calcium floccules and with angular dimensions on the order of 1-3 min, possibly having a thin structure. These regions are regions of increased radio radiation in centimeter and decimeter waves; in comparison with the rest of the corona, their electron temperature and electron density are higher. The regions of increased temperature and density begin in the lower layers of the solar atmosphere and penetrate it completely, up to the corona, stretching to an altitude of 50-100,000 km. These regions can be maintained on the Sun for a relatively long time -- on the order of solar days and longer. Evidently, the corona's regions with increased density and temperature are retained and isolated from the rest of the corona by magnetic fields on the Sun similar to the way hot plasma created in laboratory settings for research on thermonuclear reactions is retained and isolated from the walls of the chamber.

An important characteristic of coronal x-ray radiation is its spectrum. Using a spectrograph with a diffraction lattice during launches of V5V rockets on 21 June 1959, 20 September, and on 1 October 1965, in the USSR, experimental data were obtained on the investigation of the solar spectrum in the x-ray region.

On this photograph, for the first time, they captured the x-ray flash, which occurs, as recently explained, on the Sun in one of the so-called "evident spots" of activity [2].

In the period from 1965 through 1971, in the Byurakan Astrophysics Observatory, a set of instruments (K-2 and K-4) was developed for investigation of the Sun and stars on the V5V astrophysical rockets.

The rocket observatory for investigation of the Sun (K-2) is a set of various scientific instruments gathered on a special platform. They include several x-ray chambers built to receive radiation from various bands of long waves, an (externally darkened) coronograph for photographing the corona at large distances from the edge of the solar disc, a shortwave spectrograph, a camera for photographing the chromosphere and others.

In the period from 1970 through 1971, within the framework of the "Intercosmos" program, two international experiments took place on investigating the solar UV radiation on the Vertical-1 (28 November 1970) and Vertical-2 (20 August 1971) rockets with participation by specialists from the GDR, Poland, and the USSR. Using equipment developed by Polish specialists, the solar corona was photographed in several spectral ranges of the soft x-ray region of the spectrum of 8-60 Å, and in addition, spectrograms were obtained of the Sun in individual lines in the far UV band of long waves of 250-400 Å. Soviet scientists used spectrometers to record the solar corona spectrum in the long wave range of 5-20 Å. The Soviet and Polish instruments were installed on one platform which made it possible to track the Sun with an accuracy of ±1 min. The GDR specialists developed and prepared a Lyman-alpha photometer for these experiments in order to measure the intensity of the solar UV radiation in the $L\alpha$ hydrogen line (1,215.6 Å) and its absorption by the terrestrial atmosphere [10].

The importance of the research begun in 1951 on the solar shortwave radiation is in no way exhausted by the results listed by us. The development of this research preceeded along identical paths in the USSR and the U.S.A. and the results of the Soviet and American rocket research, and more recently, of the research conducted in England and France, to a significant degree complement each other. On the whole, the accumulated material quite completely characterizes the solar shortwave radiation and, at the present time, it is possible to expect the use of the data obtained to solve important questions in the prediction of solar activity and geophysics.

What is the mechanism of the solar x-ray radiation? Based on all the data obtained up to the present time, it is possible to say that in the case of the quiet Sun, this radiation is of a heat nature, i.e., that it is caused by interaction of electrons having a Maxwellian velocity distribution and ions of hydrogen, helium and the heavier chemical elements which makeup the corona's plasma.

BIBLIOGRAPHY

1. S.L. Mandelshtam, "Survey of Works on Research on Solar Shortwave Ultraviolet Radiation," UFN, Vol 46, Issue 2, 1952, p 145.
2. S.L. Mandelshtam, "Research on Solar Shortwave Radiation," "Uspekhi SSSR v issledovanii kosmicheskogo prostranstva" [The USSR's Successes in the Investigation of Outer Space], Moscow, 1963, pp 296-297, 299.
3. L.A. Vedeshin, "The Development in the USSR of Rocket Research on Near-Earth Space," in the collection "Iz istorii aviatsii i kosmonavtiki" [From the History of Aviation and Cosmonautics], Issue 15, Moscow, 1972, pp 5, 19.
4. A.A. Blagonravov, "Research on the Upper Layers of the Atmosphere using High-Altitude Rockets," Vestnik an SSSR, 1957, No 6, p 29.
5. V.P. Kachalov, N.A. Pavlenko, and A.V. Yakovleva, "Ultraviolet Spectrum of the Sun in the 2,636-2,937 Å and 2,471-2,635 Å Regions," Izvestiya an SSSR, Seriya Geofizika, No 99, 1959, p 1,099 and No 9, 1959, p 1,177.
6. A.V. Yakovleva, and L.A. Kudryavtsev, et alia, "Spectrometric Research on the Ozone Layer up to an Altitude of 60 km," in the collection "Iskusstvennyye sputniki Zemli" [Artificial Earth Satellites], Issue 14, Moscow, 1962, p 61.
7. T.V. Kazachevskaya, V.A. Arkhangelskaya, and G.S. Ivanov-Kholodnyy, et alia, "Measuring the X-ray and Ultraviolet Radiation using the Thermoluminescent Phosphor $CaSO_4(Mn)$," in the collection "Iskusstvennyye sputniki Zemli," Issue 15, p 173.
8. V.P. Kachalov, and A.V. Yakovleva, "Solar Ultraviolet Spectrum in the 2,470-3,100 Å Region," Izvestiya Krymskoy Astrofizicheskoy Observatorii, Vol 27, 1962, p 44.
9. V.V. Katyushina and V.G. Kurt, "Measurements of the Scattered L Radiation in the Upper Atmosphere at Altitudes up to 500 km," Kosmicheskiye Issledovaniya, Vol 3, Issue 2, 1965, pp 243, 248.
10. L.A. Vedeshin and M.G. Kroshkin, "The 'Vertikal-1' Geophysical Rocket," Vestnik an SSSR, Vol 3, 1971, pp 86-87.