44. ASTRONOMICAL OBSERVATIONS FROM OUTSIDE THE TERRESTRIAL ATMOSPHERE (OBSERVATIONS ASTRONOMIQUES AU-DEHORS DE L'ATMOSPHÈRE TERRESTRE)

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During the past period of 1970–1972 Space Astronomy gave us new information on the nature of the Moon, Venus, Mars, Solar activity, the interplanetary medium, and on UV and X-ray stellar astronomy. At present we are starting a new development of Space Astronomy technique: manned orbital stations with astronomical instruments ('Salyut', 'Skylab'), systematical observations of the Sun, the interplanetary medium and stars. I think, therefore, that it is reasonable to discuss the current state of space astronomy. In this review we shall not consider the scientific results, this being a matter for other IAU Commissions, but we shall mainly pay attention to the technical achievements and new possibilities of development.

THE MOON

The Apollo programme finished successfully with the launch of Apollo 17 in December 1972. Six times men from Earth visited different parts of the Moon, placed there automatic scientific stations for the exploration of the Moon as a cosmic body and collected lunar rocks.

At the same time automatic stations also visited the Moon with great success. Luna-16 (September 1970) and Luna-20 (February 1972) (**1**) made soft landings in two regions of the Moon, and took probes of lunar rocks to the Earth. On november 17, 1970 the station Luna-17 placed on the Moon the automatic mobile lunar laboratory Lunokhod-1. During 10 months this station has investigated a spacious part of the lunar surface in the region of Mare Imbrium (**2**).

Astronauts of Apollo 15, 16 and 17 had also a lunar rover and could drive to survey remote formations on the lunar surface.

The first astronomical instruments were delivered at the Moon. An X-ray telescope and devices for recording cosmic particles of small energy and for monitoring the levels of the proton activity of the Sun were mounted on Lunokhod-1. This was the first astrophysical station which operated on the Moon during 10 months.

The first small UV telescope and spectrograph was placed on the Moon on April 20, 1972 by Apollo 16. It was a small Schmidt camera with a spherical primary mirror (f = 75 mm; *F*/1·0) and correction plates. Part of the sky is imaged on the focal surface coated with a thin layer of KBr (photocathode sensitive for $\lambda \leqslant 1600$ Å). The electrons emitted from this cathode are accelerated toward the primary mirror, focussed by a magnetic field and form an electron image of the sky on the film behind a hole in the middle of the primary mirror. This camera is an original combination of a small telescope with a high focal ratio mounted inside the electronic image multiplier. The telescope may operate in two modes: one to yield direct images of the sky, and another to get the spectrum. There were two correction plates: one of LiF to get pictures in the spectral region 1050–1600 Å including the Lα line of neutral hydrogen; another, of CaF_2 with a shortwave limit at 1230 Å. Without correction plates the telescope-spectrograph has a shortwave limit of about 500 Å, due to the reflectivity of the mirror and grating. The field of view of telescope is about 20°, the spatial resolution $\approx 2'$ (**3**). The astronaut Young has obtained with this telescope more than 200 UV pictures of different parts of the sky and the Earth (**4**). We note as an important result the discovery

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of the He I λ584 Å emission in interplanetary space, caused, probably, by the interaction between interstellar gas, solar wind and solar UV radiation (**5**).

The first astronomical instruments therefore have been tested on the Moon, which opens to us the possibility of using the lunar surface as a base for astronomical observations. An important advantage in comparison with an orbital astronomical observatory like OAO-2 is the absence of the emission in Lα line of the hydrogen corona of the Earth. On the other hand a lunar astronomical telescope with a TV camera and automatic transmission to the Earth can operate quite automatically and scan parts of the sky by the slow rotation of the Moon (**6**).

PLANETS, INTERPLANETARY MEDIUM

The space station Venera-7 finished its flight and landed on December 15, 1970 on the night side surface of the planet Venus. The station Venera-8 finished its flight and landed on July 22, 1972 on the day side of the Venus surface and transmitted data for 50 min from the surface (temperature $T = 470 \pm 8\,°C$, pressure $p = 90 \pm 1{\cdot}5$ kg/cm, very close to the data measured on the night side by Venera-7). Venera-8 verified that some sunlight does reach the surface of the planet through the thick clouds and on this planet differences exist between day and night. The density of the surface layer is about 1·5 gr/cm^3. A gamma-ray spectrometer discovered 4 % K, 10^{-4} % U and $6{\cdot}5 \times 10^{-4}$ % Th in the Venus soil in the region of landing. Measurements of the UV radiation of interplanetary hydrogen were made during the flight to Venus and near this planet. A variation of factors 2–3 of this radiation was registered on different parts of the trajectory. The UV radiation (in narrow spectral bands) from bright blue stars was observed. The parameters of the interplanetary plasma and intensity of cosmic rays were also measured (**7**).

The difficult experimental problem was solved of performing a landing of automatic stations on the surface of Venus where very extreme conditions of temperature and pressure exists.

In November 1972 three man-made satellites appeared near Mars – three space stations: Mariner 9, Mars 2 and Mars 3.

The station Mars 3 released its landing apparatus which performed a soft landing on the surface of Mars and thereupon transmitted information during 20 s. It was the first landing of an automatic station on the Mars surface, and took place under a heavy dust storm. This experiment opens the possibility of a direct exploration of this planet by automatic apparatus landing on its surface. Space stations in orbits around Mars and automatic landing stations on its surface will in a near future put together a complex for the exploration of this planet. An example is the Viking spacecraft proposed to be launched towards Mars in 1975–1976; it will consist of an Orbiting station and a landing module.

A large program for the study of the Martian atmosphere and surface relief was carried out by stations Mars 2 and 3 through the registration of the radiation in a wide wavelength region from 0·4 to 4 microns. It was shown particularly that there was H_2O in the Martian clouds (**8**).

A sufficiently detailed map of the Martian surface is constructed on the basis of pictures obtained from Mariner 9 (**9**). Some interesting details of surface relief were found (**10**).

Spacecraft departing from the Earth into interplanetary space to the Moon or planets have, as a rule, different devices to study the nature of interplanetary space and the solar wind especially the events connected with solar activity. Such devices were also on the stations Mars 2 and 3. They registered during the whole flight towards and near Mars the parameters of the interplanetary plasma, magnetic fields and particle density of the charged particles. The Soviet-French experiment 'Stereo-1' investigated the spatial structure, direction and nature of the solar radio emission in the one-meter wavelength region.

Three channels UV photometry was carried out on board of Mars-3 for investigating the Martian hydrogen corona. The brightness of this corona was recorded up to a distance of about 12000 km from the Martian surface. It exceeded by 10–15 % the brightness of the interplanetary underground, being equal to 400–600 *R*. The radiation of atomic oxygen in wavelengths 1225–1340 Å (**11**) was also recorded near Mars to a height of 1000 km.

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The space station Pioneer 10 was launched on March 2, 1972 in the direction of Jupiter, with as objective the investigation of this giant planet and interplanetary space between the orbits of Mars and Jupiter (**12**). The passage of this station through the asteroid belt would give us more information about this region of the solar system. Pioneer 10 entered this belt in July 1972. A new modified station Pioneer G will be launched in the direction of Jupiter in 1973 having the same objective.

The flight of these stations is very important: they mark not only the beginning of the exploration of the giant planets but also of interplanetary space outside the Martian orbit. These stations will be present in this space during a two years flight and will transmit information about the conditions which exist there.

It is necessary to note that at the end of 1972 a group of Pioneer space stations (Pioneer 6, 7, 8, 9 and 10) are in different parts of interplanetary space: the first four are distributed over the Earth's orbit and Pioneer 10 is in the asteroid belt. Such a distribution is very advantageous for obtaining at the same time information about the events in interplanetary plasma in the region of the Earth's orbit and outside.

Two stations, Prognoz (April 14, 1972) and Prognoz-2 (June 22, 1972) were launched in an elliptical orbit (perigee 950 km; apogee 200000 km), ($P = 97$ h) for the continuous observations of events in the interplanetary medium evolving there in connection with active processes on the Sun. These satellites will measure: (1) the composition of particle fluxes, their spectra, angular distribution and intensity variation; (2) electromagnetic radiation of the active events on the Sun (ground-based solar observations in the optical and radio regions are carried out at the same time); (3) the plasma parameters in the interplanetary space and magnetosphere. The fluxes of X-ray photons (2–4 keV), γ-radiation (30–350 keV) and the parameters of the solar wind are also measured.

In August 1972 all these stations have recorded the unusual events which occurred in interplanetary space after the strong solar flares on August 2, 4 and 7. Pioneer 9 recorded the very high speed of the solar wind – about 1000 km s^{-1}. When these solar wind particles had reached Pioneer 10 their velocity was less by a factor of two, but the temperature had risen to 2×10^6 K (**13**). The satellites Prognoz recorded the strong flash-up of γ-rays up to 10^4 quanta/cm^2 s, during the flare of August 7. The velocity of the solar wind particles increased by a factor of two after the flare of August 4 and the ionic particle density was 10–20 times the mean value for the solar wind.

The space station Mariner 10 will be added to these interplanetary stations in 1973 (launch expected on October 29). Mariner 10 will pass in February 1974 along Venus and will be near Mercury in March 1974; this station will remain in regions between the orbits of Mercury and Venus at times approaching Mercury. The main objective of this station is obtaining pictures of Venus and Mercury from a short distance, the exploration of the nature of these planets, mainly the surface and atmosphere of Mercury, the discovery of an UV glow of the Venus and Mercury atmospheres and the recording of charged particles (electrons and ions) of the solar wind (**14**).

In this way the whole interplanetary space between the orbits of Mercury and Jupiter in 1974 and later will be under investigation by many space stations as well as by the stations directed to Venus and Mars for the continuation of the study of these planets.

The Solar Wind conference of Asilomare (U.S.A.) on 21–26 March 1971 summed up the information about the nature and conditions in interplanetary space by 1971. A large number of questions were discussed connected with the structure and properties of the interplanetary medium and their relation to active events on the Sun (**15**).

SOLAR RESEARCH

The space observations of the X-ray and ultraviolet emission of the Sun are being made almost continuously at different satellite systems, similar to the observations of the interplanetary medium. This is very understandable because the solar processes are responsible for the state of the plasma in interplanetary space and for the processes occurring in the magnetosphere of the Earth and its atmosphere.

One can mention a few directions of extraterrestrial research of the Sun with intense efforts in the current observations, reductions of the data obtained and preparations for new experiments. Balloon, rocket and satellite instrumentation is widely employed in these researches. We attempt to briefly characterize these directions.

The series of solar stations OSO continue to operate successfully. The OSO-7 satellite launched in September 1971 has devices for the investigation of the solar corona in the UV spectral range (170–630 Å), the white corona at distances of 3–10 solar radii, the γ-emission of the Sun in the energy range of 0·3–10 MeV and cosmic X-rays. This satellite allowed one to record the early stages of solar flares. In particular the flare of October 3, 1971 was recorded by OSO-7 and OSO-5, which gave a chance to compare the X-ray emission of this flare in a wide range of energies. An increase of energy by factors 100–1000 in the 20 keV range has been observed.

High quality images of the solar disk and the inner parts of the corona were obtained. Systematic observations of the outer solar corona during an 11 min time interval, made on December 14, 1971, gave the opportunity to determine the tangential velocity component of coronal matter, which reached a value of 1000 km s^{-1}. One could compare the ejection of this coronal matter from the solar surface with a radio burst at 25–200 MHz (**16**).

The reduction of the rich material obtained with the early OSO-4 and OSO-6 satellites was continued. An Atlas of UV-spectroheliograms obtained in the 300–1370 Å spectral range with OSO-4 with an angular resolution of 1′ was published in 1970; the time duration of the recordings was equal to 5 min for each of the spectroheliograms (**17**). OSO-4 has recorded 269 solar flares, and OSO-6 211 flares with an angular resolution of 35″ and a time resolution of 30 s (this is the time interval to obtain a spectroheliogram of active region of 7 × 7 arc min in size). The OSO-4 spectroheliograms were obtained for many spectral lines and the continuous spectrum and referred to the temperature interval 10^4–$3·5 \times 10^6$ K, for 24 different atoms and ions in various stages of ionization, from hydrogen to the resonance lines of Fe XV and Fe XVI. Spectroheliograms were obtained at OSO-6 only for the three lines O VI 1032, C II 1335 and Mg X 625 Å. Each of the flares was only recorded in a spectroheliogram for one of the spectral lines, which naturally, reduces the possibility of investigating the physical conditions in flares and their nature.

On 26–27 October, 1967 scans of the spectrum of the central part of the solar disk, outside an active region, were made by the satellite OSO-4. Thus the spectrum of the quiet Sun in the spectral range 300–1370 Å with a resolution of 3·2 Å and estimates of the energy of the emission in separate spectral lines were obtained (05.076.024). An analysis of this spectrum allowed one to determine the abundance of 10 elements in the corona and to construct a model of the transition zone of the quiet Sun and of the coronal atmosphere. The possibility of determinating the conditions in the transition zone and the corona from the lines of some ions of the iso-electronic sequence of Li I was established (**18**). A comparison of the quiet solar spectrum with spectroheliograms of OSO-4 and OSO-6 made it possible to determine the contribution of active regions in separate UV spectral lines to the emission of the solar disk as a whole. This contribution depends essentially on the kind of spectral lines and on the temperature regions where they are excited. E.g. for the lines with $\log T_e = 4·0$–$5·8$ the contribution amounts to 10 % and only for these with $\log T_e = 6·5$ it reaches 40 %, particularly for the coronal lines of Fe X and Fe XVI (03.076.007 and (**19**)).

The analysis of spectroheliograms allowed one to determine also the increase of the emission energy during a flare relative to a pre-flare stage of the same active region. This increasing changes from 10 % to several times and is strongly dependent of the physical condition in the given active region (**20**). The height of formation of separate spectral lines in active regions above the photosphere was determined; the accuracy of this evaluation is about 2000 km. It was noted that the line C II falls out of the general dependence (**21**).

On 8 July, 1971 the satellite Solrad-10 (1971–058 A) with an expected period of active operation of 3 years was launched; it is aimed at continuous solar patrol with recording of the X and UV-emission of the Sun in 12 parts of the spectral range 0·08–1600 Å. This satellite continues the series of the Solrad satellites, two of which, Solrad-9 and Solrad-10, have recorded simultaneously the emission of a number of powerful solar flares in August 1972.

In April 1973 the flight of the orbiting laboratory Skylab with a group of devices to study the solar emission in the 0·1–6000 Å spectral range is scheduled. It will be the largest experiment made from an orbital station aimed at studying solar emissions since the beginning of the extra-terrestrial solar investigations. In the special compartment of ATM there are 6 devices for obtaining a sufficiently great resolution, spatially and spectrally (**22**). These are:

(1) A white-light coronagraph with a 3° field of vision to obtain solar coronal images with a 8″-resolution in the spectral range 4900–5900 Å.

(2) A chromospheric spectrograph for the 970–3940 Å spectral range with a 2″ spatial and 0·08 Å spectral resolution in the first-order spectrum and 0·04 Å resolution in the second-order spectrum with dispersions of 8·3 and 4·4 Å/mm respectively. The aim is to derive the spectra of small features at the solar disk (flares, filaments etc.,), and also to establish changes in the spectrum from the center to the limb of the disk, to estimate the emission and absorption in the solar chromosphere.

(3) A photoelectric spectroheliometer in the 300–1350 Å spectral range. This device is similar in principle to earlier versions flown on OSO-4 and OSO-6, but with some essential changes; the instrument can perform a 'scanning' of the chosen regions of the Sun with a 5″-resolution or it can scan the spectrum with 1·6 Å resolution. The instrument will be used to obtain images of the active regions of the Sun in up to seven wavelengths simultaneously, instead of one wavelength on OSO-4 and OSO-6. This will considerably expand the possibility to study the physical nature of solar active phenomena.

(4) A full-disc spectroheliograph covering the range from 150–625 Å. It will be used to obtain monochromatic images of the solar disk with 1″.5 spatial resolution and with a spectral resolution $\geqslant 0{\cdot}1$ Å. Other small X and UV spectroheliographs of similar kinds for the range 10–200 Å will be installed in the laboratory apartment, outside ATM; it will be directed to the Sun through small window in the laboratory body. The spectral resolution is 0·04–0·08 Å (**23**).

(5) An X-ray telescope, in the soft X-ray region, will obtain photographic filtergrams of the entire disc through six different filters between 5 and 33 Å. In addition, a separate instrument with proportional counters will record the solar emission in 10 bands in the range 2–20 Å to obtain fast information by transmitting this information to the ground by telemetry channels.

(6) A grazing-incidence soft X-ray telescope will obtain filtergrams between 3 and 60 Å; it has a diffraction grating for obtaining monochromatic images for spectral analysis. The spatial and spectral resolutions are 2″ and 0·2 Å respectively. A separate photomultiplier measures the total intensity of the X-ray flux in the energy range 5–100 keV, and data are tape-recorded and telemetred to the ground.

The flight of the orbital station Skylab with this complex of equipments to investigate solar processes presents a significant development in solar research, the beginning of which was put by the OSO and Solrad stations. It should be noted that in the OSO program till 1978 the launching of three other stations is planned.

Another direction in solar research and in that of cosmic rays of small energy is carried out by satellites of the 'Intercosmos' series, with the purpose to perform systematic investigations according to a many years successive program (**24**). Among these satellites, 'Intercosmos-1' (14.10.1969), 'Intercosmos-4' (14.10.1970) and 'Intercosmos-7' (10.06.1972) study the Sun in the X and UV special ranges. They have following devices on board:

(1) An X-ray filter-photometer for the range 0·3–1·7 Å (filter Nb), an 1·7–3·5 Å (filter Fe) and an 8–14 Å (filter Al) with proportional counters for recording the emission produced by active features and flares. On the satellite 'Intercosmos-7' the spectral region 1–100 keV is divided into 8 channels.

(2) An X-ray heliograph for the range 8–12 Å with an angular resolution of 1′ on Intercosmos-1 and 20″ on the following; it scans the Sun in the angle limit 40′ by the motion of the satellite axis.

(3) An X-ray spectrometer with a plane quartzcrystal to record the solar spectrum in the range 1·85–1·87 Å (the lines of Fe XXIII–XXV) and the lines of Mg XII 8·42 and Mg XI 9·16 Å, with a resolution of 4×10^{-4} Å.

(4) An X-ray polarimeter for $\lambda \approx 0{\cdot}8$ Å measuring the polarization of solar flares and active features. In addition the UV-photometer in the range 1150–1330 Å (the Lα-region) and 1400 Å $\pm$ 50 Å, to study the constancy of the solar flux in these ranges of the spectrum, and an optical photometer

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to study the structure of the Earth's atmosphere. The registration of the Solar spectrum in the hard X-ray range was carried out also on the rocket 'Vertical-2' on 20 August, 1971.

The principal results of these investigations were reported in (**25**). They come to the following: for the quiet corona $T_e = 1{\cdot}6\text{–}1{\cdot}8 \times 10^6$ K. For flares the temperature increases up 20×10^6 K. The fine spatial structure of flare, with an angular dimension $20'' \times 1'$, is observable. For one of the limb flares its height above the photosphere was determined to be equal to 20000 km. For the first time, on the satellite Intercosmos-1, the polarization of X-ray emission in the first stage of a flare was found, which indicates the existence of a directed flow of electrons with an energy of 10–100 keV (**26**). The X-ray spectra of flares near the ranges 1·86 and 8–9 Å have been obtained and identified (**27**). The series of 'Intercosmos' satellites will be continued (**24**).

Hard X-rays of the Sun (20–1000 keV) are recorded also by a 12-channel spectrophotometer placed on the satellite ESRO TD-1A launched on 12 March, 1972, with a time resolution of 1·2–4·8 s (**28**).

Rocket research of the Sun in the X- and UV-ranges of the spectrum are carried out systematically. On the rocket Aerobee 170, on 29 April, 1971, the emission in the lines O VII and Ne IX has been recorded by a crystal spectrometer. In the spring of 1972 the X-ray solar spectrum in the range 6–23 Å has been recorded with a resolution 5×10^{-3} Å; the crystal spectrometer has scanned very rapidly, during 30 s, the spectrum of separate active regions. The spectroheliograph of the U.S.A. Naval Research Laboratory, in the flight on 4 November, 1969, has recorded a sequence of spectra in the range 170–629 Å with a high spatial resolution in monochromatic images of solar flares.

The simultaneous flight of the two rockets on 9 November, 1971 allowed one to determine the absolute increase of the solar intensity in the range 30–205 Å (one rocket) and 220–1220 Å (the other), with a spectral resolution of 0·15 and 0·6 Å respectively. These data give the possibility to find with sufficient accuracy the ratio of intensities of the lines which belong to the Li- and Be-like ions in the solar atmosphere (**16**, p. 16–18).

A rocket-borne camera obscura with an aluminium filter of 5000 Å thick, has produced an X-ray image of the Sun, which showed an X-ray flare probably connected with the prominence but not with the spot group (**29**).

The Astrophysical Research Department of the Culham Laboratory (England) has realized and now plans to launch a further series of Skylark rockets up to 270 km of height; these rockets have different equipments for solar research (**30**). Here, one should mention the study of the spectral range 13–800 Å with the aid of a grazing-incidence grating spectrograph during the flight of the rocket on 5 August, 1971, which gave new data on the spectrum of ions of the He I, Li I and Be I-sequences (04.034.074). Earlier flights of this device allowed one to record the spectrum range 13–33 Å. A spectrograph with a normal-incidence grating in the range 300–3000 Å (06.073.094) gave the spectrum of separate solar regions, projected at the entrance slit by a tracking concave mirror; the stabilization precision was equal to one arc sec. This experiment was carried out to obtain the spectrum of the disk center and of the limb to investigate conditions in the transition zone between the chromosphere and corona. The spectrum in the range 550–2550 Å was recorded during the flight on 5 August 1971. In preparation is an experiment for investigating the transition zone structure by the measurement of the limb/disk ratio in the range 165–800 Å with the purpose to derive information from the spectral lines emitted in the inner corona. The complex of three grazing-incidence grating spectrographs is under preparation; two of them will record the spectrum of the solar disk, and a third the spectrum of the limb. A stigmatic image of the Sun will be formed by a special optical system at the entrance slit of each spectrograph. The flight is scheduled for 1973.

On 22 April, 1969 and 7 April 1970, the flights of a special echelle spectrograph of high dispersion took place to obtain the spectrum of separate parts of the solar disk in the ranges 1200–2000 Å and 2000–3000 Å (05.034.018). A small degree of defocusing, caused by thermal deformation from aerodynamical heating just after the start, has been found in the first flights. Improvements were introduced in a modified device, planned for March, 1972.

Very interesting spectroheliograms of the total phase of the 7 March, 1970 solar eclipse were obtained in the range 1200–2200 Å. Here, 28 new lines in the spectrum of the multiple ions of O, S, Mg, Si, Al, Fe, Ni were observed in collaboration with scientists of Harvard and York, 21 of which have been identified (06.076.025). The performance of the experiment, which is attempted to determine the electron temperature of the selected region of the solar atmosphere by the method of relative intensities, is planned for 1975 in cooperation with the scientists of Goddard Space Flight Center.

In November 1969 a Fabry-Perot interferometer in combination with an echelle spectrograph was launched by a rocket, to record line profiles of the resonance lines Mg II 2795 and 2803 Å (06.071.061). Then this device has been adjusted for the flight on a balloon on 2 August, 1971. Four scans of the spectrum near these lines were made at a height of 40 km during 3 hours of flight.

A grazing incidence grating spectrometer with radiation being incident parallel instead of perpendicular to the grooves, was launched by the Utrecht Laboratory on 25 June 1972 to observe the XUV spectrum of the Sun between 40–70 Å with 1 Å and 1 × 6 arc min resolution of the solar disk (**31**).

Results of exceptional quality were obtained in the Pulkovo Observatory during the flight of a solar telescope and spectrograph on balloon in 1970 (06.080.029). The fine structure of the sunspot umbrae and the spectra of separate regions of the solar disk were observed with the aid of a grating spectrograph. Preliminary results of this flight were reported by V. A. Krat at the scientific session of the Commission 44 held in 1970 in Brighton.

The determination of the brightness temperature of the Sun in the far infrared range of the spectrum 0·11–0·5 mm has been made by the Geneva Observatory with the aid of a diffraction interferometer placed on the balloon (**32**).

A large program of solar research by means of original devices installed on balloons, rockets and satellites is carried out by the Laboratory of Stellar and Planetary Physics organized recently in Paris and directed by R. M. Bonnet. A summary of these investigations is given in Appendix I.

Concluding the section dedicated to extraterrestrial solar research one should note that the specificity of this research (it concerns also the stellar researches) needs the conduction of substantial experimental investigations in laboratories which have modern vacuum techniques, spectral devices and radiation sources. The problem of the calibration of both separate optical components and devices in their final form is quite important. The chemical purity of the experiment presents another very crucial question, especially for conducting research in the short wavelength UV-range. Observations by OSO-4 gave already indications of the contamination of the optical surfaces during the flight; this contamination decreases the effectiveness of the devices (04.031.025). During the operation of the orbital station Skylab it is planned to make special investigations of the processes leading to contamination (**23**). A special experiment showed that details of the electronic circuit, placed in the same volume with the optical details, can be the sources of the intensive contamination on the optics (**33**). The problem of the reflective capacity of the mirrors and of the stability of this capacity in the course of time, is quite an important problem to be studied in the laboratories (**34**).

It is very necessary also to make special experimental and theoretical investigations regarding the excitation of multiple ionic spectra in the laboratory, and their investigation (vacuum spectroscopy).

One should note the organizations where similar laboratory investigations are intensively made: (1) the spectroscopy laboratory of the Harvard Observatory, organized by Prof. L. Goldberg, (2) the Astrophysical Department of the Culham Laboratory in England, organized by Dr. Wilson and (3) the spectroscopy laboratories of the Physical Lebedev Institute and the Spectroscopy Institute of the Academy of Sciences of the USSR, organized by Prof. S. L. Mandelshtam. In these laboratories the experimental and theoretical works in vacuum spectroscopy are carried out, which are intended to interpret the results obtained by means of extraterrestrial astronomy. Note, e.g., the investigations of B. C. Fawcett (**30**, p. 29) and those of L. Vaynshteyn and Korneev (**27**). A summary of the work done by the Harvard Observatory on the maintenance of extraterrestrial solar research is given in Appendix II.

STELLAR ULTRA-VIOLET ASTRONOMY

A review of work on ultra-violet astronomy from OAO-2 in the period from 1970 to 1972 by

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A. D. Code and B. D. Savage is given in Appendix III, and the review on rocket ultra-violet astronomy by A. Boggess is found in Appendix IV.

I should like to make some general remarks concerning the development of stellar ultra-violet astronomy and give some additional comments to the reviews mentioned.

There are two trends in space astronomy to be noted. The first trend is the development of orbital astronomical satellites, representing a telescope supplied with precise guiding system and with a spectral device for recording spectra with an acceptable spectral resolution. Such was OAO-2 which successfully operated during 4 years (launched in 1968 December 7). At the end of 1972 a catalog of the OAO-2 observations was published, which contains quantitative data on ultra-violet colours and magnitudes of 5000 stars. Results of this enormous work were discussed at a special symposium (**35**).

On March 12, 1972, the astronomical satellite ESRO TD-1A was launched. This satellite was supplied with devices for studying stellar and galactic sources. Two of these devices were used for detecting cosmic rays and X-rays in the energy range of 2–30 keV and two of them were used for the ultra-violet region of the spectrum. One of them was the 30 cm mirror telescope of the Culham Laboratory and Liège Observatory supplied with a photometer and a three-channel spectrophotometer to scan the spectral region between 1350 and 2550 Å with steps of 20 Å and a pass band of 35 Å (**36**). The other was an ultra-violet spectrometer of the Utrecht Astronomical Institute with a resolving power of 1·8 Å recording spectral intervals near 2100, 2500 and 2900 Å, each interval being 100 Å wide. Preliminary results of these observations were presented at the 15th meeting of Cospar in Madrid (**37**).

In 1972 August 21 the OAO-3 (Copernicus) with a 80 cm mirror telescope was launched. This telescope had an $f/20$ Cassegrain system, supplied with a diffraction spectrometer having a concave Paschen-Runge grating (**38**). Scanning of the spectrum was performed by means of two exit slits with photomultipliers moving along the Rowland circle in the spectral region from 1500 to 3000 Å in the first and from 700 to 1500 Å in the second order of the spectrum. The spectral resolution was from 0·025 Å to 0·4 Å. The accuracy of pointing by stellar sensors was about 0″1.

That spectrometer records stellar spectra up to $m = 7$ for 90 % of the working time of satellite; 10 % of the time was given to three small X-ray telescopes to record the radiation of X-ray sources. The planned working time of the telescope is 1 year, but the working experience with OAO-2 permits one to hope for a longer time.

In 1976 the launching of a new orbital telescope into a synchronous orbit is planned. This project is developed by three organizations: NASA, ESRO and the Scientific Council of Great Britain (**39**). The telescope will record spectra of astronomical objects in the region of 1130–3360 Å with the resolutions of 0·15 Å (échelle spectrograph) and 6·5 Å (simple grating spectrograph). It is intended to obtain stellar spectra of early type stars with a resolution of 0·1 Å up to the 8th magnitude and with a resolution of 6·5 Å up to the 13th magnitude. It will be an international astronomical satellite.

The development of a 3-meter mirror orbital telescope for stellar spectra recorded in a wide range from 900 Å to 4 microns is planned (**40**).

The orbital station Salut (September 1971) contained a telescope with $f = 1400$ mm (optical efficiency $f/5$) and concave diffraction grating (Wadsworth scheme). The pointing accuracy of it was 30″. Spectra in the range of 2000–3000 Å with a resolution of 5 Å were photographed. With an exposure time of 30 min it might be possible to obtain stellar spectra up to the 5th magnitude. Cosmonaut V. I. Patsaev has obtained spectra of the stars α Ly and β Cen with different exposures (**41**).

The second trend of investigations on space ultra-violet astronomy is led by G. Courtès at the Laboratory of Space Astronomy (LAS) in Marseilles. Small optical effective telescopes are used to obtain photographic pictures of regions of the sky. A large optical efficiency requires small focal lengths, which consequently reduces the requirements for the guidance and pointing accuracy. One should only care for the image not to be shifted beyond the limits of the resolving elements of the receptor (photo-emulsion) and the required sky region should be recorded on the film.

Another opportunity of efficient optics includes the possibility of recording very faint stellar objects. The spectral intervals are singled out either by filters or by diaphragms arranged in the optical scheme of a diffraction spectrometer. Such was the device prepared for installation in the laboratory cabin of the orbital station Skylab. With a guiding accuracy of 7′, photometric marks (instead of stellar images) are obtained which permit one to perform accurate photometry of stars and faint extended objects in two spectral intervals between 1800 and 3800 Å. Such is also the double night camera Janus to be used for taking photographs of stellar fields simultaneously in two spectral intervals singled out be a dichroic filter (06.051.023).

A photoelectric spectrometer with high optical efficiency is prepared for the French satellite D2B planned for launch in 1976. These spectrometers are to be used for recording the zodiacal light and the antisolar region in a wide spectral range (about 1000 Å) near 4000 Å with a television camera for identifying stars in the area and for photometry of stellar images (**42**).

Attention is to by paid to the rocket program FAUST for investigating stars in the ultra-violet region, developed by G. Courtès (**43**). The large optical efficiency telescope is mounted on a stabilized platform pointed by stellar sensors with an accuracy of 15′ in the direction of the observation. Direct pictures of parts of the sky are recorded on photographic plates through UV filters. The realization of this program will begin in 1973. It is expected to record stars of *m*-15.

The experience of the LAS permits one to expect that the one meter telescope with large efficiency (*f*/1·0) will record stars up to $m = 20$. The possibility of recording such very weak stellar objects in two or more parts of the UV region is very promising for modern astronomical problems since many interesting objects (pulsars, quasars, X-ray sources) are very weak.

It should be noted that rocket UV astronomy has good prospects of development, both in the increase of the flight altitude, as well as in the capability of lifting the heavier scientific instruments (**44**).

We should also note the possibilities of UV stellar observations with balloon-borne scientific instruments to heights of about 40 km where one may record the spectrum between 2000 Å and 3000 Å.

Such stellar research is carried out by the Observatory at Geneva observing the emission of light near 2200 Å from the Orion region of the sky (05.131.109); a prism-objective Schmidt-camera was used to record low resolution spectra between 2000–5000 Å (**45**).

The Lunar and Planetary Laboratory has a continuing program of IR Spectroscopy and Photometry from aircraft, concerning the observations of the infrared sources. An additional technical development is the construction of a guidance system for such observations (**46**).

CONCLUSION

Space Astronomy opened to us new regions of scientific knowledge. We can now observe and study grandiose events in interplanetary and interstellar space. A great many events in interplanetary space connected with solar activity and their influence on the magnetosphere and biosphere of the Earth became clearer to us.

The unlimited possibilities of recording different aspects of high energy physics are opened. It is evident now that it is necessary to study systematically the Sun-Earth relations and the events on the Sun and in the interplanetary space. The orbital stations like OSO, Solrad, Intercosmos and many others are called for such important works.

It is also necessary to study the nature of the stars, the galactics and interstellar medium – this is an advanced line of research of the physics of elementary particles.

Astronomy today discovers the nature of the events taking place on the Earth and important for life on one hand, and the natural elementary events in the deep interior of matter. Just in this aspect we must count on the exceptional importance of astronomical observations both on the ground and outside the Earth's atmosphere (**47**).

I am extremely grateful to all colleagues who have sent me information on space atronomy.

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President of the Commission

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APPENDIX I

REPORT FROM LABORATOIRE DE PHYSIQUE STELLAIRE ET PLANÉTAIRE, VERRIÈRES LA BUISSON

R. M. Bonnet

L.P.S.P. is a Laboratory deeply involved in space research. The bulk of its program is Solar Physics and Astronomy in the UV and IR ranges. The period extending from 1970 to 1972 has been characterized by a very intense activity in Balloon, Rocket and Satellite experiments.

1. *The balloon program*

This program is headed by Dr. P. Lemaire and D. Samain. It takes advantage of the relatively good transparency of the atmosphere in the near UV down to 2750 Å and around 2100 Å at altitudes of 38 km which are easily reached by the French balloon.

P. Lemaire and D. Samain have designed very high spectral resolution spectrometeres (20 mÅ) for the study of the Mg II resonance lines at 2800 Å and the C I forbidden line at 1994 Å.

These instruments are made of all-reflective optics and make use of concave gratings as dispersive elements. The use of the double Wadsworth mounting makes it possible to obtain stigmatic spectra of the sun. The instruments are pointed to the sun by means of a biaxial pointing system specially developed at L.P.S.P. In P. Lemaire's instrument, the pointing accuracy is strongly improved up to one arc second by servo controlling the secondary mirror of the Cassegrainian telesope.

Both instruments were launched several times from Aire-sur-L'Adour in France and gave very important and good results (06.071.053).

2. *The rocket program*

L.P.S.P. is also deeply involved in the preparation of rocket experiments. The experiments will be launched before the end of 1972. All experiments deal with the UV spectrum of the sun.

The first experiment will attempt to make photographic pictures of the solar spectrum between Lyman alpha 1216 Å and 2100 Å. The instrument is stigmatic and allows a point by point study of the disc surface as well as center to limb studies. The inclusion of a small servo system in the instrument improves the pointing accuracy up to something better than one arc second. The spectral resolution is only 0·3 Å.

The purpose of the experiment is to make limb darkening measurements and study the variation in altitude of the inhomogeneities of the solar atmosphere.

The launch is scheduled for October 1972 on a Veronique 61 rocket from French Guyana.

The second experiment will calibrate the solar spectrum with an aimed absolute accuracy of 5% between 2700 Å and 2900 Å. This region includes the two resonance lines of Mg II and is also very rich in faint absorption lines. Apart from the calibration of Lemaire's balloon spectra of the Mg II