44. COMMISSION DES OBSERVATIONS ASTRONOMIQUES AU-DEHORS DE L'ATMOSPHERE TERRESTRE

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Introduction

Many important advances in the techniques of space astronomy have occurred since the last General Assembly. The most widely publicized developments have been those connected with the exploration of the Moon and Mars, where the exploits of such spacecraft as Luna, Zond, Surveyor, Lunar Orbiter and Mariner in revealing the details of the lunar and Martian landscapes have seemed little short of miraculous. The photographs obtained during these flights have already been extensively disseminated and the results of more detailed analysis are best left to Commissions 16 and 17. Although the lunar and planetary developments have been of the highest scientific importance, the space program has also had a number of other successes of equal scientific significance, although characterized by a much more modest scale of engineering achievement. Many types of satellites and space probes have provided detailed measurements of the interplanetary plasma and its associated magnetic fields. The discovery of a sizable number of extra-solar X-ray sources has already established a new branch of astronomy, which has attracted numerous experimenters and captured the attention of many theoretical physicists. Far ultraviolet stellar spectra have been photographed for the first time, both from sounding rockets and with cameras operated by astronauts in the Gemini spacecraft. Solar X-ray astronomy has also advanced very rapidly. X-ray photographs of the Sun are approaching in resolution those made in visible light. Solar X-ray spectra now reveal emission lines down to a wavelength of 6 Å and seem to defy all limitations imposed by 'reasonable' coronal temperatures.

Unlike lunar and planetary astronomy, which has profited greatly from advances in large-rocket propulsion, solar and stellar astronomy continue to derive most of their benefits from small rockets and satellites. The usefulness of sounding rockets will be even greater when triaxial pointing controls, pioneered in the U.K. with the Skylark rocket, become more generally available. On the whole, the large orbiting observatories have not yet produced the results expected of them both because of technical difficulties and also a certain amount of bad luck.

In recognition of the expanding volume of results and publication in space astronomy, this year's Draft Report has been sub-divided into three separate reports prepared by L. Goldberg, L. Houziaux and R. Lüst, and dealing respectively with solar astronomy, galactic astronomy and solar corpuscular radiation. I am grateful to Drs Houziaux and Lüst for their valuable contributions.

Appendices to this Report, dealing with Soviet investigations, are added at the end.

L. GOLDBERG
President of the Commission

SOLAR ASTRONOMY

(by Leo Goldberg)

1. *Introduction*

Anyone wishing to become acquainted with the literature of space astronomy will find many useful review articles and volumes at his disposal. Most of the papers presented at IAU Symposium No. 23, held at Liège in August 1964 have been published in the *Annales d'Astrophysique* and collected into a single volume edited by J. Steinberg (**1**). The proceedings of the COSPAR symposia held in Florence, Italy in 1964, in Buenos Aires, Argentina in 1965 and in Vienna, Austria in 1966 should also be consulted. A good review of the problems of solar physics and of the relevance of space techniques to their solution is contained in the Proceedings of the Summer Conference held in June 1965 at Woods Hole, Massachusetts (**2**). Other parts of the same volume contain similar reports published in behalf of optical stellar astronomy, radio astronomy, and X-ray astronomy. The end product of each report is a series of recommendations for the long range development of large facilities to be deployed in space by 1980. Several reviews deal with the XUV solar spectrum and its interpretation (**3–6**) while others are more concerned with techniques (**7–10**).

Every effort has been made, in the preparation of this report, to include all results of solar observations from space vehicles that were published or otherwise brought to my attention by preprints or correspondence prior to 1 December 1966. The Bibliography will be found to be more complete in sections dealing with techniques and results than in those concerned with interpretation, which is more fully treated in the reports of other Commissions.

2. *Spacecraft, Instrumentation, Future Experimemts*

2.1 *NASA projects*

Plans for future experiments in space astronomy in the U.S.A. and in Europe were described in detail at the meeting of Commission 44 during the 12th General Assembly and published in Volume XIIB of the *Transactions of the IAU*. The following up-to-date revision of the NASA program has been supplied through the courtesy of Drs H. J. Smith and N. G. Roman. Satellite vehicles now being employed for the purposes of astronomy include the Orbiting Astronomical Observatory (OAO), Orbiting Solar Observatory (OSO), Orbiting Geophysical Observatory (OGO), Radio Astronomy Explorer (RAE), Apollo, Solar Explorer and Apollo Telescope Mount (ATM). The Advanced Orbiting Solar Observatory (AOSO) program was cancelled in 1965 and many of the experiments transferred to other spacecraft, such as the ATM, a manned solar observatory designed to provide angular resolution of better than five seconds of arc. Radio Astronomy Explorer is an orbiting radio telescope composed of two 750 foot (23 m) V antennas intended both for mapping galactic noise between one and seven MHz and for measuring radio bursts from the Sun and Jupiter in the range 300 kHz to 7 MHz. The first ATM mission will carry five instruments as follows:

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1. White light coronagraph	High Altitude Observatory
2. Ultraviolet coronal spectrographs	Naval Research Laboratory
3. Spectrographic X-ray telescope	American Science and Engineering Co.
4. Ultraviolet scanning spectrometers	Harvard College Observatory
5. High resolution X-ray telescope	Goddard Space Flight Center

Four launches of OSO spacecraft, designated D, E I, F and G, have been approved, with experiments as shown in the following table:

OSO–D

Pointed section

Spectroheliometer, 3–75 Å	Giacconi and Paolini, American Science and Engineering Co.
Crystal Spectrometer 0–8 Å.	Chubb, Friedman, Kreplin, Meekins, Naval Research Laboratory.
Spectrometer-Spectroheliometer 300 Å–1300 Å.	Goldberg, Reeves, Parkinson, Harvard College Observatory.

Wheel section

Solar X-ray Photon Counter, 1–70 Å.	Boyd, University College, London; Pounds, University of Leicester.
Location Soft X-ray Sources.	Gursky, Giacconi, American Science and Engineering Co.
Lyman-α in Earth's Corona.	Mange, Chubb, Friedman, Naval Research Laboratory.
Solar X-ray Monitoring.	Kreplin, Naval Research Laboratory.
High-energy Protons and Electrons.	Waggoner, Univ. of California.
Solar Monitoring He II 304 Å.	Boyd, Stewardson, University College London.

OSO–E I

Pointed section

Solar Spectroscopic Monitoring, 250 Å–1300 Å.	Hinteregger, Hall, Air Force Cambridge Research Laboratory.
Solar Spectroscopic Monitoring 1–400 Å.	Neupert, White, Goddard Space Flight Center.

Wheel section

Earth Albedo 3200 Å–7800 Å.	Ames Research Center.
X- and Gamma-rays from Cosmic and Solar Sources, 7–190 KeV.	Peterson, Univ. of California.
Arrival Direction Cosmic Gamma Rays > 100 MeV.	Kraushaar, Clark, Garmire, Mass. Inst. of Technology.
Low Energy Solar X-rays, 8–14 Å.	Teske, Univ. of Michigan.
Cosmic and Solar Charged Particles, Gamma Rays.	Kaplon, Deney, Denrik, Univ. of Rochester.

OSO–F

Pointed section

Location Regions on Sun of Soft X-rays 3–18 Å.	Boyd, Willmore, University College, London; Pounds, University of Leicester.
XUV Spectroheliograph, 284–1216 Å.	Purcell, Detwiler, Tousey, Naval Research Laboratory.
Solar Spectroscopic Monitoring 1–400 Å.	Neupert, White, Goddard Space Flight Center.

Wheel section

Profile Solar and Geocoronal Lyman-α.	Blamont, Centre National Recherche Scientifique.
Solar X-ray Monitoring 0·5–60 Å.	Chubb, Kreplin, Friedman, Naval Research Laboratory.
Low Energy Solar and Cosmic Gamma Rays.	Frost, Horstman, Roth, Goddard Space Flight Center.
Polarization Zodiacal Light.	Ney, Univ. of Minnesota.
Solar XUV Monitoring, 280–1030 Å.	Rense, Parker, Univ. of Colorado.

OSO–G

Pointed section

Offset Pointing Spectrometer-Spectroheliometer, 300–1300 Å.	Goldberg, Reeves, Parkinson, Huber, Harvard College Observatory.
Location and Spectra Solar X-rays 1–60 Å.	Kreplin, Chubb, Meekins, Friedman, Naval Research Laboratory.

Wheel section

Solar XUV Monitoring in Lines of He, O and N.	Boyd, Woodgate, University College London.
Solar X-ray Line Monitoring, 16–40 Å.	Argo, Bergy, Evans, Henke, Los Alamos Scientific Laboratory.
Brightness, Polarization Zodiacal Light.	Carroll, Aller, Rutgers University.
Solar X-rays and Gamma-rays, 2–200 KeV.	Brini, University of Bologna.
High Energy Neutrons 20–130 MeV.	Leavitt, University of New Mexico.

2.2 *ESRO projects*

Dr B. Bolin has communicated an account of ESRO spacecraft and experiments, to be launched during the next few years. Those concerned with solar astronomy are as follows:

ESRO I: polar orbit of 90° inclination; apogee 1500 km; perigee 275 km; total weight 78 kg; scheduled for launching September-November 1967. Experiments include the measurement of auroral particles and solar protons in five experiments by three different groups, namely, (1) Kiruna Geophysical Observatory, Dr. Hultqvist; (2) Science Research Council, Slough, Dr Dalziel; (3) Ionosphere Laboratory, Lyngby. Mr Peterson is coordinator of all five experiments.

ESRO II: near polar orbit of 98° inclination; spin stabilized; apogee 1100 km; perigee 350 km; scientific payload 20 kg; scheduled for launching, March 1967; intended for studies in the field of cosmic rays and solar astronomy, of cosmic rays in interplanetary space, modulation mechanism of primary cosmic radiation; electron component, solar corpuscles and electromagnetic radiation and trapped protons of the inner Van Allen belt. Solar experiments include (1) Study of the variations of X-rays below 20 Å from the quiet Sun, with five proportional counters, by Boyd, University College, London and Stewardson, University of Leicester; (2) Study of the variations of X-rays in the region 44–70 Å, with two proportional counters, by de Jager, Utrecht Observatory; (3) Measurement of flux and energy spectrum of solar protons (35 MeV–1 GeV) with telescope comprising solid state detectors, by Labeyrie, Centre d'Etudes Nucléaires de Saclay.

TD–1: the first ESRO medium size stabilized (Sun pointing) satellite; near polar circular orbit of 98° inclination; altitude 560 km; scientific payload 80 kg; scheduled for launching in early 1970. Two solar experiments are (1) Monitoring of solar X-rays, 40–300 KeV with scintillation counter, by de Jager, Utrecht Observatory and (2) X-ray spectrometry 3–30 KeV, with proportional counter, by Labeyrie, Saclay. A second satellite in the series, TD–2, is a solar maximum satellite, to be launched

TD–1: by an improved Thor Delta during the latter part of 1969 into an orbit of as yet undetermined inclination, with apogee 1200 km and perigee 350 km. The satellite will carry a number of solar experiments: (1) High resolution spectrometry of solar X-ray emission with a crystal spectrometer, by Stewardson, University of Leicester; (2) Monitoring of the profile of the solar Lyman–α line, with a hydrogen or deuterium cell and photomultipliers, by Blamont, C.N.R.S.; (3) Monitoring of solar particles (13–160 MeV protons) with a solid-state detector telescope, by de Jager, Utrecht Observatory; (4) Monitoring of solar particles (0·6–28 MeV protons) with a scintillator employing solid state detectors, by Lüst, Max Planck Institute, Munich; (5) Extreme ultraviolet solar spectrography, with a spectroheliograph, by Boyd, University College, London.

HEOS–A: inclination of orbit 33°; apogee 240 000 km; perigee 200 km; spin stabilized, scheduled for launching in July 1968, will carry eight experiments for the measurement of particles and fields in the interplanetary medium.

2.3 *Other proposed experiments*

2.3.1 *Utrecht Observatory*. According to C. de Jager, the new Space Research Laboratory of Utrecht Observatory participated or is participating in the following projects: (1) Rocket observations of soft solar X-rays (44–60 Å), in the French national program, and with ESRO (launchings in 1964, 1965, 1966). Precise measurements of the soft X-ray flux were obtained during the years of solar minimum activity. (2) A satellite experiment in the same wavelength band has been prepared for launching in the ESRO II satellite in April 1967. (3) Balloon launchings for the detection of hard solar X-ray bursts between 20 and 600 KeV take place regularly. (4) An extreme ultraviolet and X-ray solar heliograph will be flown early in 1967 in a sun-pointing NASA rocket at White Sands. The heliograph is based on the Fresnel-type zone plate principle and is designed to obtain solar images in Si IX 51 Å; Fe VIII–X 180 Å; He II 304 Å and He I 584 Å. (5) A high-resolution solar spectrophotometer for the region 44–64 Å is in preparation for flight in an ESRO sun-pointing rocket in November 1966.

2.3.2 *University of Tokyo*. Dr Z. Suemoto reports that an institute of space and aeronautical science was established in 1964 in the University of Tokyo to promote the further development of space and aeronautical science in Japan. It is expected that the facilities of the new institute will be utilized by scientists in relevant fields of research throughout Japan. The new institute has a launching site at Uchinoura Kagoshima in Kyushu, which began operation late in 1963. Typical sounding rockets now in use in Japan are the K–9M, which carries a payload of 60 kg to a maximum height of 350 km and the L–3 with a payload of 110 kg and a maximum height of 1100 km. The so-called MU rockets, which are capable of launching satellites, are under development and satellite projects are being seriously considered. To date only some preliminary experiments on the height variation of the solar Lyman–α flux have been performed (11).

2.3.3 *Stockholm Observatory*. Dr Y. Öhman reports that he is designing a spectrograph for recording the spectrum of various parts of the solar surface from an unstabilized rocket. The instrument uses a large number of small lenses placed on a spherical surface. The focus of all these lenses is situated in the center of curvature. Here a very small (about 0·5 mm) reflecting sphere is used, functioning as a slit for a spectrograph. By using a continuously moving film, tracings are obtained when the various lenses happen to project the solar image on the small sphere. The instrument is mainly intended for the study of the Mg II lines at 2800 Å in solar flares. Dr K. Fredga is developing an improved instrument for recording solar images in the Mg II line at 2802·7 Å for flight in the near future. J. O. Stenflo has started the design of a spectrograph, which he hopes to use in space research for studying solar magnetic fields in small structure elements of the solar surface.

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2.3.4 *Meudon Observatory*. Dr A. Dollfus reports as follows on his plans to photograph the solar corona from high altitude balloons:

'En ce qui concerne plus particulièrement les activités de mon laboratoire, je prépare une série de vols en ballons, depuis le Centre de Lancement de Aire-sur-Adour (Landes) pour la photographie des grands jets de la couronne solaire. L'instrument est un petit coronographe précédé d'une poutrelle portant un cache à 4 mètres en avant de l'objectif et destiné à porter ombre sur celui-ci, afin de réduire la lumière diffusée à un facteur 10^{-8}; le contour de ce cache est formé de 360 dents de 0·45 mm de profondeur afin de diminuer la brillance de la lumière réfractée par ce contour. La nacelle stabilisée et le dispositif de pointage automatique ont été construits par la Société Française 'Compagnie des Compteurs'. Le ballon de 50 000 m^3 en feuille plastique de polyéthylène de 40μ d'épaisseur atteint l'altitude de 30 000 mètres. Le premier vol est prévu pour le début de l'année 1967.'

2.3.5 *University College, London*. At the University College, London, R. L. F. Boyd and his collaborators are planning to make accurate absolute measurements of the flux of solar Lyman α at intervals in the solar cycle. An experiment to study the center to limb variation in Lyman α was to be flown during the annular solar eclipse of 15 May 1966. The University College group in collaboration with Leicester are preparing satellite-borne instruments containing arrays of proportional counters to study the wavelength bands 1–20 Å and 44–70 Å on board OSO–D and the band 1–20 Å on ESRO II.

2.3.6 *Imperial College*. Dr R. Speer, Imperial College, U.K., has called attention to a unique opportunity to observe XUV radiation at the solar limb with very high spatial resolution during the solar eclipse of March 1970, which passes over the Wallops Island Launching Facility of NASA. He comments that:

'The azimuth, geographic coordinates and speed of the umbra permit trailing stabilised rocket trajectories capable of yielding chromospheric limb scan rates in the range 0·2 to 0·4 seconds of arc per second of time. It is proposed that, at minimum, three stabilised Aerobee 350 rockets be launched, carrying modified STRAP control systems. These launchings will occur at equal intervals during a three-minute period centred around maximum eclipse. It is suggested at this stage that a carefully chosen selection of emissions be made from ions of H I, He I, He II and the Li-like iso-electronic series, together with a portion of the continuum at 1400 Å–1600 Å associated with the chromospheric/photospheric temperature reversal. A measurement of the Balmer α line of helium II at 1640 Å, if combined with observations of the other helium II lines outside of eclipse would provide the first direct measurement of helium abundance in the chromosphere.'

2.3.7 *Geneva Observatory*. Professor M. Golay is preparing to launch a rocket equipped to carry out photoelectric photometry of the Sun in several regions of the UV spectrum.

3. *Solar Ultraviolet, X-rays and Gamma Rays*

Most observations of the Sun's XUV radiation during the past two to three years have been made in the short wavelength region below 500 Å. Important gains have been made in spectroscopic resolution, in the mapping of the ultraviolet solar spectrum above the limb, in the spatial resolution of ultraviolet and X-ray images and in X-ray spectroscopy. Most of the results have been obtained by the use of sounding rockets, but small satellites have played an important role in the monitoring of X-rays.

3.1 *Solar Spectra*

The high resolution échelle spectrograph first flown in 1961 by the Naval Research Laboratory was reflown on 19 November 1964 and the solar spectrum extended from 2200 Å to 2100 Å (3). No measurements from either of these spectra have been reported but there are plans to publish a list of lines with identifications and an atlas showing intensity profiles. With the aid of a new tri-axial stabilization system developed for the Skylark rocket, the Culham Laboratory flew a spectrograph on 9 April 1965 with the entrance slit placed about ten arc sec outside the solar limb (**12, 13**). Photographs of the ultraviolet spectrum between 950 Å and 2950 Å show about 300 emission lines, including intersystem transitions in C III, N IV, O V and new forbidden transitions in Fe XI and Fe XII (**14**). New measurements of absolute fluxes in the solar XUV spectrum were made by photoelectric scanning from 310 Å to 55 Å (**15, 16, 17**) and by photography in the spectral intervals 250 Å to 370 Å and 33 Å to 70 Å (**18**). Absolute fluxes in the spectral region from 1750 Å to 1 Å have been tabulated for relatively quiet solar conditions (**19**).

The first recordings of solar X-ray spectra with a Bragg crystal spectrometer were carried out in 1963 to a short-wavelength limit of 13 Å (**20**). In the U.S.S.R., photographs and spectra of the Sun in short-wave ultraviolet and X-radiation were obtained with apparatus on board two geophysical rockets, which attained heights of nearly 500 km on 20 September and 1 October 1965 (**21**). During the 1 October flight, photographs and spectra of the Sun were obtained for the first time during the beginning stages of an X-ray flare. During the flare, the intensity of the Fe XVII line at $\lambda = 15{\cdot}0$ Å increased by two orders of magnitude as compared with its intensity in the absence of solar flares. A review of the variability of the solar X-ray spectrum below 15 Å has been published (**22**), based on U.K. observations with sounding rockets and the Ariel satellite during the period 1959–63. H. Friedman reports the observation by NRL, on 4 October 1966, of solar X-ray emission lines identified with Na XI, Mg XI, Al XII, Si XIII and Si XIV in the spectral region 6 Å to 8 Å.

3.2 *Ultraviolet images*

The first monochromatic photographs of the Sun in the Mg II line at 2802·7 Å were obtained with a Cassegrain-Maksutov telescope and a Solč-type birefringent filter on board an Aerobee rocket on 12 April and 2 December 1965 (**23**). A photoionization detector behind a pinhole placed at the focus of a Cassegrain telescope of two seconds of arc resolution recorded the fine structure of the Sun in Lyman α during an Aerobee flight on 20 October 1965 (**24**). Rapid progress is being made in the improvement of techniques for solar imaging at extreme ultraviolet and soft X-ray wavelengths. The Culham Laboratory in the U.K. has developed a compact extreme ultraviolet spectroheliograph in which a pinhole camera is combined with a plane diffraction grating used at grazing incidence (**13**). The instrument was flown in a stabilized Skylark rocket on 9 April 1965 and recorded monochromatic images at 304 Å (He II), 171 Å (Fe IX), and strongly limb brightened emission in the wavelength band between 60 Å and 150 Å. High quality monochromatic images have recently been obtained by the Naval Research Laboratory with a normal incidence concave grating spectroheliograph in such lines as Fe XV 284 Å, Fe XVI 335 Å 361 Å, He II 304 Å, and many others, the most recent flight having taken place on 28 April 1966 (**25**). The emission in the strongest lines was observed to extend five arc minutes or more beyond the limb. Accordingly, a photographic extreme ultraviolet heliograph, consisting of an off-axis paraboloidal mirror, with filters transmitting a band from 171 Å to about 400 Å, was flown on 27 July 1966 and revealed emission above active regions extending at least to thirty arc minutes above the limb (**26**).

3.3 *X-ray images*

The distribution of X-ray emitting sources over the solar disk has been studied in four different ways: (1) from the widths of X-ray emission lines observed with a Bragg crystal spectrometer (**20**), (2) by means of slit scans of the solar disk in broad X-ray wavelength bands (**20**), (3) by pinhole photography (**27–30**) and (4) by photography with a grazing incidence imaging telescope (**31, 32**). The newest observations (**32**) suggest that X-ray images may soon be recorded with spatial resolution of one second of arc or better.

3.4 *Monitoring of Solar X-ray Emission*

The Solrad satellites of the Naval Research Laboratory have been monitoring the total flux from the Sun in the three wavelength ranges 2–8 Å, 8–20 Å and 44–60 Å. Results have been reported from three such satellites, 1963–21–C (**33**) 1964–01–D (**34, 35, 36**), and 1965–16–D (**37**). Observations made by the Injun I satellite during the second half of 1961 at wavelengths shorter than 14 Å have also been reported (**38**). The first orbiting solar observatory monitored solar X-rays at 2–8 Å and at 20–100 keV (**39**). The 2–8 Å X-ray flux was found to be highly variable, comprising a slowly varying component that correlated well with plage activity and additional variations in time periods ranging from one second to several hours (**40**). A number of high energy bursts accompanying solar flares were observed in the 20–100 keV range (**41**). Observations of solar X-rays in wavelength bands peaked at about 2 Å and about 4 Å were made from a Vela satellite during the period 18 October to 1 November 1963 (**42**). An important set of measurements of the spectral energy distribution of solar flare X-rays was carried out with a low-resolution proportional counter spectrometer for the region 4–14 Å on board the U.K. satellite Ariel I between 26 April and 1 November 1962 (**43, 44**). Soft X-radiation from the Sun in two spectral intervals, 2–10 Å and 8–18 Å, were carred out during flights of the cosmic stations Electron II and Electron IV in the U.S.S.R. (**45**). Measurements with the Electron II station extended from 30 January to 16 March 1964. The X-ray flux was well correlated with the area of active spots, with the flux of radio radiation at 10·7 cm wavelength and with the flux of radio radiation from discrete sources at 6·6 cm wavelength. Many X-ray flares were observed both with and without the accompaniment of chromospheric flares. Two cases were observed in which X-ray flares were associated with an increase in the flux of heavy nuclei with $Z > 15$ (**46**). No indication of a statistically significant flux of solar gamma rays in the energy range up to 10 MeV could be detected from balloon measurements of the quiet Sun (**47, 48**).

4. *Visible and Infrared Radiation*

Observations of visible and infrared solar radiation and of the zodiacal light have been carried out from aircraft, balloons, rockets and satellites. The solar spectrum from 140–1000 cm^{-1} was recorded with a Michelson interference spectrometer flown in a balloon on 10 August 1965 (**49**). Jet aircraft were employed at the eclipse of 20 July 1963 for the observation both of the coronal spectrum $\lambda3700$–$\lambda4900$ (**50**) and of the solar corona at large distances from the Sun (**51**). Coordinated observations of the corona from the solar limb to the zodiacal light were also carried out during the same eclipse from the ground, from a balloon at 100 000 feet (30 km) altitude and from a jet aircraft (**52**). White light coronagraphs were also flown in stratospheric balloons on 5 March 1964 (**53**), 3 June 1965 and 1 July 1965 (**54**), and from Aerobee rockets on 28 June 1963 (**55**) and in 1966 (**56**). The balloon observations in 1965 were closely coordinated with ground observations including those during the total solar eclipse of 30 May 1965. During this eclipse, profiles of the emission line $\lambda5303$ were obtained with a Fabry-Perot interferometer (**57**) from an aircraft instrumented by the Los Alamos Scientific Laboratory. On 14 June 1966, the outer solar corona was photographed with the Surveyor I television camera on the surface of the Moon after the solar disk had set behind the western horizon (**58**). The corona was traced out to an estimated 3 to 4 solar radii from the center of the disk and a very prominent coronal streamer, corroborated by ground-based measurements, was also apparent.

A Japanese K–9M rocket was flown on 26 July 1965 with equipment to measure the zodiacal light photoelectrically at three wavelengths, 4300 Å, 5300 Å and 6000 Å (**59**). The measured region was approximately 40° to 15° from the Sun, which covers the well-known gap between the observation of the zodiacal light and of the corona. The zodiacal light was also observed at 5000 Å and 4200 Å from a balloon flown by H. Tanabe and M. Huruhata of the Tokyo

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Observatory at an altitude of 25 km on 27 September 1966. Photoelectric measurements of the zodiacal light were obtained from apparatus in the wheel section of OSO II, beginning in February 1965 (**60**).

5. *Laboratory and Theoretical Spectra, Identifications*

The very large number of unidentified lines in the ultraviolet solar spectrum continues to challenge astrophysicists and laboratory spectroscopists. It has been suggested that many of the unidentified solar emission lines below λ1500 may be attributed to the attachment of quarks to ions of C, N and O (**61, 62**). Considerable progress has been made in the identification of lines in the region 25–250 Å (**63–70**). All of the strong lines in the solar spectrum between 167 Å and 220 Å have now been classified and identified by means of a number of ingenious laboratory techniques, (**71–74**). At the Culham Laboratory the wave numbers of lines are traced back along an isoelectronic sequence to well-classified ions. Another way of differentiating between atomic spectra and high stages of ionization is to photograph the spectra separately with two sources of considerably different excitation (**75–78**). Nearly all of the strong lines from 167 Å to 188 Å in the solar spectrum arise from the ions Fe VIII–Fe XII. Intense lines between 188 Å and 220 Å are shown to be due to unclassified lines of Fe XII–Fe XIV. The majority of the emission lines in the solar spectrum in the range 60 Å–170 Å are due to Fe and Ni, mostly the former. Other solar emission lines in the region from 310 Å to 55 Å have been identified on the basis of term differences in the tables of atomic energy levels (**79**).

The resonance lines of Fe XIV have not been observed in the laboratory and therefore their solar identification presents a special problem. One aid to identification is the requirement that two lines having a common upper state and terminating in the ground term must be separated by an amount corresponding to the wave number of the forbidden line 5303 Å (**3**). The intensity variations of extreme ultraviolet lines observed from the OSO–1 satellite also provide added clues to the identifications (**80–82**). It has been shown that the very low electron density in the solar corona relative to laboratory sources causes anomalies in the relative intensities within certain multiplets, notably the P–D multiplet of Fe XIV at 210–220 Å (**73**).

Shock-excited absorption spectra of solar-abundant atoms and molecules are being produced in the Shock Tube Laboratory of the Harvard College Observatory to assist in the identification of the solar spectrum between 3000 Å and 1500 Å. The identification of the fourth positive system of CO in the solar spectrum by this technique (**83**) has now been confirmed in detail at the Naval Research Laboratory (**84**).

6. *Problems of Interpretation*

6.1 *Opacity near* 1600 Å

The recognition that bound-free absorption by Si I and Mg I (**85**) and band absorption by the fourth positive system of CO (**83**) are the major sources of opacity in the spectral region 1550 Å–1800 Å has provided a fresh basis for the interpretation of solar radiation from the region of the temperature minimum at the interface photosphere-chromosphere. New discussion of possible models of the region of the temperature minimum has been carried out in conjunction with careful laboratory measurements of the relevant cross-sections (**86**). Improved measurements of energy distribution and limb darkening are required for a definitive model. Various methods of correcting for instrumental broadening of the solar ultraviolet limb darkening profile have been investigated (**87**). Theoretical profiles for the solar autoionizing lines of Al I at λ1930 show that at the limb the profiles are extremely sensitive to the choice of model and may possibly exhibit emission reversals (**88**). The profiles of Lyman α scattered by free electrons in the solar corona have been calculated for a number of points above the solar limb (**89**).

6.2 *Emission line intensities*

A new method for computing the total intensities of emission lines formed out of thermodynamic equilibrium (**90**) has been applied to compute the intensities of the solar ultraviolet lines and continua of H, He I and He II (**91, 92**). Another investigation deals with the formation of the Lyman continuum in an isothermal atmosphere (**93**). Both electron temperature and density may be inferred from the observed total intensities of Lyman α and β (**94**). Extreme ultraviolet line intensities inferred theoretically from radio emission measures are at least ten times stronger than those observed (**95**). The discrepancy can be eliminated by invoking an inhomogeneous model. The method of analysis originally developed by Pottasch for the derivation of chemical abundances in the solar corona from far ultraviolet line intensities has been rediscussed in two separate investigations in which the ratios Fe to Si (**96**) and Fe to H (**97**) are found to be approximately ten times greater than in the photosphere. Other investigators obtain relative abundances of heavy elements (**98**) and abundances relative to H (**99**) which are consistent with those found in the photosphere. The abundances of C, Mg, S and Al relative to Si also seem to be consistent with photospheric abundances according to line intensities observed in the spectral regions 40–62 Å and 256–356 Å (**100**).

6.3 *X-ray emission*

The interpretation of the X-ray emission from the quiet Sun and from flares has received a great deal of attention. Solar X-radiation has been classified as quasi-thermal (emitted from quiet Sun, active regions and flares) or nonthermal (emitted from solar flares only) with a further sub-division for flare associated bursts (**101**). Detailed calculations (**102, 103**) support the assumption of a thermal origin of X-ray radiation from the quiet Sun and from active regions. Above 15 Å, the main contribution to the spectrum is from lines of C, N and O. At wavelengths shorter than 15 Å, the chief contribution is from recombination of highly ionized species of the same and other elements (**102, 104**). In the absence of solar flares, the radiative flux consists of a quasi-constant component generated in the undisturbed region of the corona on which is superposed a slowly varying component generated in the hotter, denser, active regions of the corona. It can be shown that when the emission measure and the electron temperature of active regions in the corona are derived from radio spectroheliograms of the Sun at a wavelength of 10·7 cm, the calculated and experimental values of the X-ray flux are in good agreement (**103, 105**). A number of detailed theoretical investigations concerned with possible mechanisms for the origin of X-ray flares have been carried out in the U.S.S.R. Compton scattering of thermal photons by relativistic electrons has been examined (**106–108**) as well as the thermal synchrotron radiation of accelerated electrons (**109**). The inverse Compton effect has been criticized on the grounds that any quantity of relativistic electrons producing a measureable amount of inverse Compton photons will always produce a greater flux of high energy Bremsstrahlung photons than has been observed (**110**). It has been suggested that electrons with energy in the range 10–30 keV, which are produced during solar flares, may ionize atoms through K-shell ionization and that the resulting X-rays would contribute to the total X-ray emission of flares (**111**). The expectations with respect to gamma-ray emission have been calculated for a simple model of a solar flare (**112**). The detection of such radiation from a flare seems feasible.

6.4 *Ionization equilibrium*

The importance of dielectronic recombination as a major factor in the theory of ionization equilibrium of the solar corona is now firmly established (**113**). A convenient general formula has been provided for the calculation of the relevant rates which may surpass the corresponding radiative rates by 1 to 3 orders of magnitude (**114**). The collisional excitation of autoionizing levels and subsequent ionization may in individual cases increase the rate of ionization by about a factor of 2 (**115**).

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ASTRONOMIE GALACTIQUE

(préparé par L. Houziaux)

I. *Véhicules Spatiaux, Instruments et Projets*

I.1. *Observations astronomiques sur orbite* (*OAO, U.S.A.*)

Aucun exemplaire de cette série de plates-formes hautement stabilisées n'a pu encore être mis en oeuvre avec succès. Le premier OAO emportait à son bord un ensemble de télescopes destinés à la photométrie des étoiles et nébuleuses entre 1000 et 4200Å. Le 'Célescope' de la Smithsonian Institution avait été remplacé par:

(*a*) un détecteur de rayons gamma de haute énergie (préparé par le M.I.T.),

(*b*) un détecteur de rayons X, de la Lockheed Missiles and Space C°,

(*c*) un détecteur de photons ayant des énergies comprises entre 2000 et 18 000 eV, mis au point par le Goddard Space Flight Center. Malheureusement, quelques heures après la mise sur orbite, le 8 avril 1966, une température excessive a endommagé les batteries du véhicule et la mission d'observation n'a pu être exécutée.

Une nouvelle tentative de lancement doit avoir lieu dans le courant de 1968. La charge utile sera composée des deux expériences prévues primitivement pour l'OAO I (Célescope du Smithsonian Astrophysical Observatory et photométrie ultraviolette des étoiles de l'Université de Wisconsin).

Deux autres véhicules OAO sont actuellement prévus. Le premier emportera un télescope Cassegrain de 36 pouces (91 cm) destiné à la spectrométrie à haute résolution d'étoiles, de nébuleuses et de galaxies.

Cette expérience est préparée par le Goddard Space Flight Center. L'Observatoire de l'Université de Princeton (L. Spitzer et J. B. Rogerson) (1) se propose de placer sur orbite, en 1970, un télescope de 40 pouces (102 cm) équipé d'un spectrographe d'un pouvoir résolvent de 10^4 et permettant la spectrophotométrie stellaire dans le domaine de 1000Å à 3000Å.

La Nasa étudie actuellement la possibilité et l'intérêt d'effectuer des observations astronomiques à partir de satellites habités. Ce programme débuterait par une version de l' 'Apollo Telescope Mount' (Programme d'Application Apollo) permettant l'observation des étoiles. En particulier, l'Observatoire de Princeton projette la réalisation d'un télescope dont le pouvoir de résolution serait limité par la diffraction, et stabilisé à 0″01. Il pourrait être utilisé soit par un observateur humain, soit de façon atomique.

I.2. *Projets d'expériences par satellites dans le cadre de l'Organisation Européenne de Recherches Spatiales* (2)

L'Organisation Européenne de Recherches Spatiales se propose de mettre sur orbite, d'ici à 1970, cinq satellites. Les deux premiers (dénommés ESRO I et ESRO II) doivent être lancés par des fusées américaines 'Scout' sur des orbites polaires. Les trois autres satellites (dénommés HEOSA, ESTER et ESSOR) seront placés sur leur orbite par des fusées Thor-Delta améliorées.

En ce qui concerne l'astronomie galactique, nous noterons les expériences suivantes:

ESRO II: (apogée 1100 km, périgée 350 km, poids: 73 kg, date prévue pour le lancement: avril 1967).

'Mesure du flux et de la distribution d'énergie des électrons produits par le rayonnement cosmique primaire dans le domaine d'énergie des GeV'. Cette expérience est préparée par le Département de Physique de l'Université de Leeds (P. L. Marsden).

ESTER: (orbite circulaire quasi-polaire à 560 km, stabilisation par pointage vers le Soleil et par gyroscopes, poids 400 kg, date prévue pour le lancement: fin 1970).

(*a*) 'Spectrométrie de charge des particules cosmiques primaires'. Centre d'Etudes Nucléaires de Saclay, France (J. Labeyrie).

(*b*) 'Spectrométrie des photons X d'énergie comprise entre 3 et 30 keV provenant de l'espace'. Centre d'Etudes Nucléaires de Saclay, France (J. Labeyrie).

(*c*) 'Spectrographie stellaire dans l'ultraviolet', Observatoire d'Utrecht (Pays-Bas) (C. de Jager).

(*d*) 'Levé du Ciel dans l'ultraviolet entre 1250 et 3000 Å et dans l'infrarouge entre 1 et 3 microns'. Observatoire Royal d'Edimbourg et Institut d'Astrophysique de l'Université de Liège.

L'expérience (*c*) doit permettre l'obtention des spectres d'environ 200 étoiles avec une résolution de 1 Å, dans trois régions spectrales de 100 Å de large, situées entre 2000 et 3000 Å. Quant à l'expérience (*d*) (3) son but essentiel est de permettre de dresser une carte du Ciel dans quatre bandes de longueurs d'onde (de 100 Å ou 200 Å de large) situées entre 1250 Å et 3000 Å, ainsi que de procéder au recensement des sources célestes émettant une partie appréciable de leur rayonnement dans l'infrarouge. Le télescope de 25 cm de diamètre qui pointe dans une direction opposée à la Terre, est fixe par rapport au satellite et le balayage du Ciel est obtenu par le mouvement même du satellite, dont l'orbite doit précesser de 1° par jour.

L'Organisation Européenne prévoit également le lancement vers 1972 d'un grand satellite astronomique (800 kg) destiné à la spectrographie à haute résolution des étoiles entre 950 et 3000 Å.

I.3. *Autres projets*

Plusieurs séries de fusées sondes doivent être lancées par l'Organisation Européenne de Recherches Spatiales en 1967 et 1968. Parmi les expériences intéressant l'astronomie galactique, nous noterons:

(*a*) trois expériences de photométrie et spectrophotométrie à larges bandes stellaires dans l'ultraviolet, placées sur des fusées 'Skylark' non stabilisées (Observatoire Royal d'Edimbourg, J. W. Campbell et G. C. Sudbury).

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(*b*) deux expériences de photographie du Ciel dans l'UV à l'aide d'un télescope de Schmidt, à placer sur des fusées stabilisées (Observatoire Royal d'Edimbourg, H. E. Butler).

(*c*) une expérience de spectrographie stellaire dans l'ultraviolet dans la région de 1200 à 3000 Å, avec une résolution de 1 Å, nécessitant l'utilisation d'une fusée Skylark pointant avec une précision de 5′ d'arc (U.K. A.E.E., Laboratoire de Culham, R. Wilson). D'autres expériences de spectroscopie stellaire dans l'ultraviolet sont aussi projetées par le Max Planck Institut für Extraterrestrische Physik, München, et l'Institut d'Astrophysique de l'Université de Liège.

A Joddrell Bank, un groupe de chercheurs prépare pour le satellite UK–3, une version améliorée de l'instrument destiné à un levé du ciel sur 1 ou 2 MHz, qui a déjà volé à bord d' 'Ariel 2'. Cette nouvelle expérience a pour but de mesurer l'émission radio d'origine galactique à des fréquences trop basses pour être observées du sol. Le pouvoir de résolution doit être suffisant pour arriver à séparer du flux isotrope les composantes provenant du plan et du halo galactiques.

Aux Etats-Unis plusieurs groupes étudient la possibilité de mettre sur orbite une antenne de grandes dimensions, pour étudier le ciel dans la bande de 1 MHz. Cette antenne pourrait atteindre un diamètre de plusieurs milliers de pieds de diamètre. Le groupe de radio astronomie de l'Université de Michigan a mis à l'étude la réalisation d'un 'kilometer-wave orbiting telescope' (KWOT). Il s'agirait d'un treillis de 10 km de diamètre supporté par quatre satellites auxiliaires. Ce treillis serait attaché en son centre à un observatoire principal. Le système tournerait sur lui-même avec une période de deux heures et l'axe de rotation pourrait être incliné au moyen de fusées auxiliaires, de sorte que le ciel tout entier pourrait être étudié. La résolution angulaire à 1 MHz serait suffisante pour mesurer plusieurs douzaines de radiosources galactiques et extragalactiques. On pourrait aussi établir la carte du bruit radio d'origine cosmique à différentes fréquences entre 0·1 et 10 MHz.

II. *Résultats*

II.1. *Rayonnement ultraviolet d'origine galactique*

A. Observations. Une fusée Skylark, lancée de la base de Woomera, le 14 juillet 1965, a permis au groupe de recherches spatiales de l' 'University College' de Londres d'obtenir les flux émis par des étoiles chaudes dans trois régions spectrales entre 1450 et 2800 Å. Les trois photomètres étaient placés au foyer d'un télescope de 35 cm aligné selon l'axe du véhicule. L'attitude de la fusée était déduite de signaux fournis par un senseur lunaire, des senseurs d'horizon et des magnétomètres. La brillance du ciel entre 1650 et 3000 Å a été mesurée à Woomera le 25 mars 1966 par le groupe de l'Observatoire Royal d'Edimbourg.

Le groupe de l'Observatoire de Kitt Peak a lancé du champ de tir de White Sands (N.M.) un spectromètre stellaire. L'instrument était destiné à obtenir des spectres à moyenne résolution d'étoiles de la constellation d'Orion dans le domaine spectral 1050 à 2000 Å. Le spectromètre photoélectrique était attaché à un télescope de 30 cm de diamètre.

Au début de juin 1965, une équipe de l'Observatoire de Princeton, dirigée par D. C. Morton, a obtenu les premiers spectres photographiques d'étoiles chaudes montrant des raies d'absorption dans l'ultraviolet. L'instrument, lancé de la base de White Sands (N.M.) se composait de deux réseaux-objectifs montés sur une plate-forme stabilisée. Le système de pointage, fourni par la Space General C8 a permis de garder le spectrographe dirigé sur l'étoile avec une précision de $\pm$ 16″, ce qui correspond à une résolution de 1 Å,

Le 2 juin 1965, les spectres de δ et π Scorpii ont été obtenus aux longueurs d'onde supérieures à 1260 Å, à l'aide d'une chambre photographique de Schmidt, ouverte à *f*/2, pourvue d'une lame correctrice en fluorure de calcium (7). 29 raies d'absorption ont pu être mesurées dans

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ces deux étoiles B de la séquence principale. Les raies de Si IV à 1394 et 1403 Å, ainsi que la raie de C IV à 1549 Å ont été identifiées comme étant d'origine stellaire. Par contre, les raies de O I à 1302 Å, C II à 1335 Å, Si II à 1527 Å et Al II à 1672 Å sont probablement dues à l'absorption par le milieu interstellaire.

Un spectrographe similaire lancé le 13 octobre 1965 et pourvu d'une lame correctrice en fluorure de lithium, a permis de photographier les spectres de δ, ϵ, ζ, η, ι et κ Orionis à des longueurs d'onde supérieures à 1200 Å (**8**). Les images d'ordre zéro d'autres étoiles du champ ont servi à calibrer les spectres en longueurs d'onde, avec une précision avoisinant l'angström. Des raies d'émission observées à 1403 Å et à 1549 Å dans le spectre de ϵ et ζ Orionis ont été identifiées comme appartenant respectivement aux ions Si IV et C IV. Des raies d'absorption intenses des deux composantes du doublet de Si IV et du doublet non résolu de C IV observés dans ϵ, ζ et ι Orionis sont fortement déplacées vers le violet et indiquent des vitesses de 1800, 1900 et 3800 km s^{-1} respectivement. Le doublet de Si IV dans δ Orionis révèle une vitesse d'approche de 1400 km s^{-1}. Ces raies de résonance, qui apparaissent en absorption, doivent trouver leur origine dans des couches gazeuses s'échappant des étoiles à grande vitesse, indiquant par là une perte de masse pour ces géantes et supergéantes. Une raie d'absorption, large de 9 Å, présente à 1216 Å dans δ et ζ Ori, est attribuée par Morton à $L\alpha$ interstellaire.

Un nouveau vol a eu lieu le 24 mai 1966. Le spectrographe, ouvert à $f/2$, contenait cette fois uniquement des éléments d'optique par réflexion et a permis l'obtention du spectre de ζ Ophiuchi. Une erreur de pointage dans le système de contrôle d'attitude a déplacé la région spectrale et l'a amenée entre 2250 et 3670 Å, où aucune raie n'était suffisamment intense pour être mesurée avec quelque précision. Lors du vol du 20 septembre 1966, de nouveaux spectres ont été photographiés à l'aide d'un instrument similaire aux précédents, mais où le réseau et les deux miroirs avaient été traités au fluorure de lithium, afin de donner un pouvoir réflecteur maximum aux courtes longueurs d'onde. Morton a obtenu ainsi les spectres de γ, δ, ϵ, ζ, η, ι et σ Orionis à partir de 1100 Å. En plus des raies observées précédemment, on peut y découvrir de nombreuses raies nouvelles en absorption (notamment C III à 1175 Å), grâce à l'amélioration de la résolution et l'élargissement du domaine spectral exploré.

Une nacelle de ballon partiellement stabilisée a été lancée à diverses reprises par le groupe de recherches de l'Observatoire de Genève (**11**), sous la direction de M. Golay. Ces lancements, effectués à partir de la base française d'Aire-sur-Adour, à l'aide de ballons de 50 000 m^3 ont montré qu'il était possible d'effectuer avec cette technique des observations de photométrie ultraviolette jusqu'à 2204 Å. Un vol effectué en automne 1966 a permis l'obtention de spectres à faible dispersion grâce au petit télescope de Schmidt, auquel était adjoint un prisme-objectif. K. Hallam du Goddard Space Flight Center a préparé un télescope pour la spectroscopie ultraviolette par satellite. L'instrument a été mis sur orbite au début de février 1965, dans la partie inférieure du satellite OSO B2; les résultats sont actuellement à l'étude.

Le laboratoire de Physique Appliquée de la Johns Hopkins University a obtenu, de son côté, des résultats intéressants (**6**) à partir d'un télescope monté sur satellite et équipé d'un photomètre à bande passante de 204 Å centrée sur 1376 Å. Un indice de couleur ultraviolet ($m_{1376} - V$) a pu être calculé pour 96 étoiles. Ces données ont permis de déduire une échelle de température pour les étoiles chaudes, échelle qui indique une diminution de 2000 à 3000° par rapport aux températures actuellement admises. L'extinction interstellaire, à 1376 Å, tirée des mêmes observations se monte à $10{\cdot}7 \pm 6$ magnitudes, dans une échelle ou $A_v/E(B - V) = 3{\cdot}1$ et $E(B - V) = 1$.

Lors du vol de l'engin Gemini 10, le 19 juillet 1966, les astronautes Young et Collins ont photographié le spectre ultraviolet de la partie sud de la Voie Lactée. Cette observation a été faite dans le cadre du programme du Centre de Recherche Astronomique Lindheimer, Northwestern University, Ill. (K. G. Henize et L. R. Wackerling) (**9**). La caméra Maurer, de

73 mm de distance focale était munie d'un réseau par réflexion et d'une lentille transmettant l'ultraviolet jusqu'à 2200 Å. Les spectres ont été pris du dehors de la cabine Gemini. Pendant que le pilote, à l'aide de fusées auxiliaires, annulait les oscillations du véhicule, le second astronaute pointait la région du ciel choisie et la photographiait. Par suite d'un déplacement du réseau, la région photographiée est celle de γ Velorum et non celle de β Crucis comme il avait été prévu; la résolution spectrale a été fortement réduite. Les spectres de 54 étoiles ont néanmoins été obtenus.

Pendant la mission de Gemini 11, les observations ont été continuées avec un matériel plus perfectionné. Les astronautes Conrad et Gordon ont pu disposer d'un réseau objectif (dispersion 180 Å/mm) et d'un prisme-objectif permettant une dispersion de 1500 Å/mm à 2500 Å. K. G. Henize rapporte que les spectres de 99 étoiles ont été obtenus à l'aide du réseau-objectif dans les régions de λ Scorpii, Canopus et ϵ Orionis. La magnitude visuelle 5·0 peut être atteinte pour les étoiles B des premiers types. Le doublet de Mg II à 2799 Å est très intense dans le spectre de Canopus, de même que les raies ultimes de Fe II vers 2400 Å. Le spectre de Sirius montre aussi les raies de Mg II, ainsi que la discontinuité de Balmer. Les spectres obtenus au prisme-objectif montrent clairement la discontinuité de Balmer pour les étoiles B. Les multiplets dûs aux métaux apparaissent dans les étoiles de type F entre 2400 et 2800 Å, ainsi que dans 48 Librae. μ Leporis, étoile à manganèse, montre une discontinuité importante de l'hélium, tandis que l'étoile de Wolf-Rayet HD 156385 révèle vers 2300 Å une émission due à C III (2297 Å).

E. R. Mustel rapporte que des observations de champs stellaires dans les régions 3700–5500 Å et 2200–3000 Å ont eu lieu à partir du satellite 'Cosmos 51', à une altitude de 300 à 400 km. La brillance du ciel s'est révélée être de deux à trois fois plus forte que prévue. Elle serait d'environ 190 étoiles de magnitude 10 par degré carré (**10**).

Au Goddard Space Flight Center, A. Boggess (**12**) a obtenu de nouvelles mesures photométriques d'étoiles B à 2100 et 1300 Å. A 2100 Å, des étoiles de même type spectral présentent des variations d'intensité importantes, ce qui n'est pas le cas à 1300 Å.

A. Boggess a pu aussi photographier à l'aide d'un réseau-objectif des spectres d'étoiles dans la région d'Orion entre 4000 et 1300 Å. La résolution est de l'ordre de 8 à 10 Å. T. Stecher (**13**) a continué ses recherches photométriques sur les étoiles chaudes dans l'ultraviolet, en vue d'en déduire une échelle de température.

Byram, Chubb et Werner (**14**) ont mesuré la brillance d'une soixantaine d'étoiles chaudes dans la bande 1050 à 1180 Å; ils trouvent un déficit en ultraviolet stellaire par rapport aux modèles d'atmosphère.

T. Gehrels rapporte qu'un prototype de polarimètre, composé de deux télescopes Cassegrain de 7·5 cm de diamètre, équipés de prismes de Wollaston, a été essayé sur des ballons à haute altitude. La brillance du ciel a été mesurée à 2200 et 2820 Å, et la polarisation de la lumière de la Lune a été évaluée à 2900 Å. Lors d'un vol à 36·5 km d'altitude du Polariscope (réflecteur de 71 cm de diamètre), Gehrels a pu mesurer à 2200 et 2820 Å la polarisation de la lumière de ζ Ophiuchi par le milieu interstellaire.

B. *Interpretations et prédictions du spectre ultraviolet*. Les problèmes généraux ont été examinés par Seaton (**15**). Boggess et Borgman (**16**) ont déterminé l'extinction de la matière interstellaire à partir de l'observation de 6 étoiles O9·5 – B1, à 2600 et 2200 Å. Les deux points obtenus ne semblent pas s'accorder avec la courbe théorique de Van de Hulst, l'extinction continuant à augmenter lorsque la longueur d'onde décroît. Spitzer, Dressler et Upson (**17**) ont calculé les largeurs équivalentes des raies interstellaires de H_2 qui pourraient apparaître en absorption dans le spectre d'étoiles O et B. Brandt (**18**) suggère de mesurer l'abondance de l'hydrogène moléculaire interstellaire par l'étude de la raie Raman de H_2 à 1280 Å excitée par $L\alpha$.

Byram, Chubb et Friedmann (19) n'ont pu confirmer, après un second vol, la présence d'émission nébulaire autour de Spica. Cette émission, si elle existe, a une intensité inférieure à 10^{-5} erg cm^{-2} s^{-1} ster^{-1} entre 1225 et 1345 Å. Signalons encore différentes études théoriques sur les propriétés absorbantes des grains de graphite (Wickramasinghe, **20**, **21**), de l'ion He^- (Somerville, **22**) et de la quasi-molécule d'hydrogène (Solomon, **23**). La présence de cette quasi-molécule ne peut expliquer l'absorption trouvée vers 2400 Å dans le spectre des étoiles B, pas plus que le complexe He H^+ (Werner, **24**). L'influence de l'effet de serre dû aux raies d'absorption intenses dans l'ultraviolet sur la structure atmosphérique des étoiles B a été étudiée par Morton (**25**), Mihalas et Morton (**26**) ainsi que par Avrett et Strom (**27**), et Guillaume (**28**). Les profils des raies spectrales ultraviolettes ont été calculés par Morton (**29**), Guillaume, Van Rensbergen, Underhill (**30**) et Houziaux (**31**). Elst (**32**) a prédit l'absorption de rayonnement par les raies spectrales dans le domaine 1900 à 3000 Å pour une étoile B. En comparant les résultats d'observations photométriques d'étoiles B, Heddle (**33**) montre l'importance d'effectuer des mesures absolues du flux. E. M. Burbidge (**34**) a discuté l'aspect du spectre ultraviolet des galaxies et la possibilité d'observer $L\alpha$ dans leur spectre. Nicol'ski (**35**) a calculé des modèles pour des régions entre la photosphère et l'atmosphère extérieure des étoiles. Houziaux (**36**) a publié des prédictions de flux de rayonnement stellaire pour divers types spectraux et différentes magnitudes visuelles dans l'ultraviolet, en tenant compte de l'effet de l'absorption interstellaire. Houziaux et Honnay (**37**) ont étudié l'influence de l'erreur de pointage et du manque de stabilité d'un télescope à bord d'un satellite sur la précision des mesures photométriques ultraviolettes, dans le cas de l'amas de Praesepe. Agapov et ses associés ont examiné la question des observations d'étoiles à partir d'un télescope placé sur la Lune (**38**).

II.2. *Rayons X et γ d'origine galactique*

L'étude des rayons X et γ d'origine galactique, tant du point de vue de l'observation que du point de vue de la théorie, a fait de grands progrès depuis la dernière assemblée de l'UAI.

Lors du symposium de Liège, en 1964, Bowyer, Byram, Chubb et Friedmann (**39**) ont donné les résultats de mesures obtenues à l'aide de compteurs de Geiger montés sur des fusées non stabilisées. Dix sources ont été identifiées, dont la nébuleuse du Crabe et la source intense Sco X-1. Fisher, Clark, Meyerott et Smith (**40**) font part du repérage d'une source de rayons X mous vers $\alpha = 23^h\,40^m$ et $\delta = +78°$. Fisher et Meyerott (**41**) ont aussi mesuré le rayonnement X dans la bande 2–8 Å; ces résultats ont été contestés par Bowyer (**42**). Fisher, Johnson, Jordan et Meyerott (**43**) ont découvert huit sources à faible latitude galactique, mais aucune source n'a été détectée dans la direction de la supernova de Kepler ou du centre galactique. De nouvelles observations ont été faites par Byram, Chubb et Friedmann (**44**) en 1965. L'émission de rayons provenant de restes de supernovae a été examinée par Morrison et Sartri (**45**) et par Peterson, Jacobson et Pelling (**46**) (nébuleuse du Crabe). La distribution des émetteurs de rayonnement X dans la Galaxie a été étudiée par Johnson (**47**), qui suggère l'existence de deux types de sources: des sources formant un anneau autour du centre galactique, et des restes de supernovae. Un balayage du ciel a été effectué dans le domaine d'énergie 20–200 keV par Brini et ses associés (**48**). Un article récent de Giacconi et Gursky résume la situation (**49**). Hayakawa (**50**) a pu déterminer l'allure du spectre pour le rayonnement X galactique et pour les sources Sco X-1, Tau X-1 et les sources situées dans le Cygne. La source céleste la plus intense, appelée Sco X-1 a fait l'objet des travaux de plusieurs groupes (**51**, **52**, **53**). Découverte en 1962, sa position a été précisée récemment à moins d'une minute d'arc près (Gursky ***et al.*** **54**). Son identification a été faite par Oda en juin 1966, à l'Observatoire de Toyko, et confirmée par Sandage à l'Observatoire du Palomar. Il s'agit d'un objet de 13ème magnitude, très bleu, dont le spectre, qui contient des raies d'émission d'hydrogène et d'hélium ressemble à celui d'une vieille nova. Cette étoile présente des variations de brillance pouvant aller jusqu'à une magnitude en 24 heures. Sa variabilité a été confirmée par l'examen des plaques du Harvard College Observatory. Sur la base de considérations relatives à l'indice de couleur

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de cet objet, Matsuoka, Oda et Ogawara déduisent qu'il serait situé à 200 pc environ. L'histoire de la découverte et de l'identification de Sco X-1 est rapportée par Gursky (**55**). Sco X-1 a été identifiée indépendamment par H. M. Johnson et B. Stevenson.

La nébuleuse du Crabe a été étudiée à partir de ballons dans le domaine d'énergie supérieure à 15 keV par Clark (**56**). Les techniques expérimentales pour l'étude du rayonnement X d'origine extra-terrestre ont été revues par Boyd (**57**) et Mayer (**58**).

En ce qui concerne les rayons γ, Helmken rapporte que des observations ont été faites à partir de fusées dans le domaine 500 MeV à 5 GeV. Pour le rayonnement d'énergie supérieure à 10^{11} eV, il compte observer la distribution de la radiation Čerenkov dans le ciel nocturne à l'aide d'un collecteur de 34 pouces (86 cm) en construction au Mont Hopkins (Arizona). Ce système, ouvert à $f/0{\cdot}7$ et composé de 252 miroirs hexagonaux, peut être dirigé à un dixième de degré près vers n'importe quel point du ciel La sensibilité du système va jusqu'à 10^{-10} à 10^{-11} photons cm^{-2} s^{-1} pour les énergies supérieures à 10^{11} eV.

C. Fichtel et D. Kniffen ont recherché les sources ponctuelles de rayons γ, en utilisant des émulsions nucléaires orientées à partir de ballons. Le domaine d'énergie étudié va de 10 à $2{\cdot}10^3$ MeV, l'efficacité étant de l'ordre de 10% entre 10 et 50 MeV. Cobb, Duthrie et Stewart (**59**) ont estimé le flux émis dans les rayons γ par la nébuleuse du Crabe.

Des résultats d'observations de rayons γ sont donnés par Kraushaar (**60**), Long, Porter, Weeks, Fruin et Jelley (**61**), Ögelman, Delvaille, Greisen (**62**) (à l'aide de ballons), et Kraushaar, Clark, Garmire, Helmken, Higbie et Agogino (**63**). Balasubrahmanyan, Hogge, Ludwig et McDonald ont étudié le rayonnement cosmique de faible énergie (20 MeV à 1 BeV) en utilisant une combinaison de compteurs à scintillation et de compteurs Čerenkov à partir des satellites OGO et IMP et de ballons. Le spectre décroît rapidement en intensité dans la région inférieure à 100 MeV par nucléon pour les protons et les particules alpha.

Il n'y a pour l'instant aucune explication satisfaisante de l'émission de rayons X, surtout pour les sources intenses comme Sco X–1. Les différentes hypothèses (étoiles à neutrons, couronnes stellaires, rayonnement synchroton) ont été envisagées et étudiées par de nombreux auteurs (références **64** à **93**).

II.3. *Rayonnement infrarouge*

Les principaux résultats ont été obtenus par l'équipe de Princeton, à l'aide du Stratoscope II, un télescope de 36 pouces (91 cm) monté à bord d'un ballon. N. J. Woolf (**94, 95, 96**) a exposé au symposium de Liège les résultats du second vol de cet instrument, où ont pu être observés les spectres de Mira Ceti, Aldébaran, μ Geminorum, ρ Persei, R. Leonis, μ Cephei, Bételgeuse. Les bandes les plus remarquables sont celles de H_2O, à 1·4, 1·9 et 2·7 microns, qui absorbent 1/4 à 1/3 du continuum local. L'intensité de ces bandes augmente fortement avec la luminosité intrinsèque de l'étoile. Danielson, Gaustad et Woolf ont cherché à identifier la bande à 3·1 μ due à la glace interstellaire, mais la présence de cette bande n'a pu être établie avec certitude. Danielson a étudié le problème de l'opacité due à la molécule d'eau pour les étoiles de basse température (1700 à 3400 °K). Cette opacité est très importante et surpasse toutes les autres sources connues à des températures inférieures à 25000 °K.

Gould (**97**) a étudié théoriquement la présence et l'intensité de raies d'émission infrarouges provenant des régions H II, des enveloppes stellaires, des régions H I interstellaires, des proto-étoiles pendant la phase de contraction, des nébuleuses planétaires et de l'hydrogène moléculaire interstellaire. Stein (**98**) s'est intéressé à l'émission infrarouge par des grains interstellaires pour les longueurs d'onde supérieures à 10 μ.

II.4. *Rayonnement de basse fréquence*

Lors du symposium de Liège, F. G. Smith (**99**) a passé en revue les observations aux ondes de basse fréquence obtenues à bord de véhicules spatiaux, et les a confrontées aux résultats

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obtenus à partir du sol. Au-dessous de 5 MHz, le rayonnement est principalement d'origine extragalactique. Au-dessous de 2 MHz, on observe une absorption qui paraît isotrope et due à une région H II centrée sur le Soleil. Huguenin et Papagiannis (**100, 101**) ont observé le rayonnement hertzien dans l'espace aux longueurs d'onde supérieures à 30 m. Aux altitudes comprises entre 3000 et 11 000 km, le flux a une valeur voisine de celle qui est prévue sur 2·2 MHz, alors que sur 0·7 MHz, le niveau reçu dépasse la valeur prévue de 15 db. Il est possible que cette dernière observation puisse s'expliquer par le rayonnement cyclotron des ceintures de Van Allen et de la ceinture artificielle. Hartz (**102**) a rapporté les observations faites à partir du satellite canadien Alouette II entre 1·5 et 10 MHz. La région du ciel la plus brillante sur 2·3 MHz est centrée sur le pôle galactique sud. La région la moins brillante à 2·3 MHz a pour coordonnées 9^h00^m et + 75°. La courbe représentant la température de brillance en fonction de la fréquence présente une pente de − 1·3 à 1·5 MHz, − 1·7 à 2·3 MHz et − 2·2 à 5 M Hz.

Alexander et Stone (**103**) ont mesuré à l'aide de fusées le bruit cosmique à 1·91, 2·85, 3·60 et 4·70 MHz.

Smith (**104**) a analysé les résultats obtenus à l'aide d'instrumentation placée à bord du satellite Ariel II, qui a relevé la brillance du ciel à 1–2 MHz. La brillance mesurée est compatible avec la contribution attendue de l'espace extragalactique. Mais, aux fréquences inférieures à 2 MHz, sa diminution donne à penser qu'elle est absorbée par l'hydrogène ionisé de notre Galaxie.

Weyman et Chapman (**105**) ont étudié la possibilité de détecter les couronnes stellaires aux radiofréquences.

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SOLAR CORPUSCULAR RADIATION

(prepared by R. Lüst)

1. *Introduction*

During the last three years our knowledge about the solar corpuscular radiation—now called the solar wind—has increased considerably due to many measurements carried out from satellites and space probes. Table 1 gives a list of the satellites and space probes which had instruments on board for measuring the interplanetary plasma and magnetic fields.

Table 1

Satellites and space probes equipped for measuring interplanetary plasma and magnetic fields

Vehicle	Launch date	Apogee	Plasma instrument	Magnetometer
Pioneer 1	Oct. 11, 58	18·6 R_e	—	Search coil
Lunik 1	Jan. 2, 59		Plasma trap	Triaxial fluxgate
Lunik 2	Sept. 12, 59		Plasma trap	Triaxial fluxgate
Lunik 3	Oct. 4, 59		Plasma trap	Triaxial fluxgate
Pioneer 5	March 11, 60		—	Search coil
Venus 1	Feb. 12, 61		Plasma trap	?
Explorer 10	March 25, 61	46·6 R_e	Plasma cup	Rubidium
Mariner 2	Aug. 26, 62		Electr. analyzer	Fluxgates
Explorer 14	Oct. 3, 62	16·4 R_e	Electr. analyzer	Triaxial fluxg.
Vela 1, 2	Oct. 17, 63	17 to 20 R_e	Electr. analyzer	Search coil
IMPI(=Ex.18)	Nov. 27, 63	31 R_e	Plasma cup and electr. analyzer	Rubidium fluxg.
Vela 3, 4	July 17, 64	17 to 20 R_e	Electr. analyzer	Search coil
OGO 1	Sept. 5, 64	24·4 R_e	Electr. analyzer	Search coil
IMP 2	Oct. 4, 64	16 R_e	Electr. analyzer	Rubidium fluxg.
Mariner 4	Nov. 28, 64		Plasma cup	Helium
IMP 3	May 29, 65	41·7 R_e	Electr. analyzer	Rubidium fluxg.
Vela 5, 6	July 20, 65	17 to 20 R	Electr. analyzer	Search coil
Venus 3	Nov. 16, 65		Plasma trap	?
Pioneer 6	Dec. 16, 65		Plasma cup and electr. analyzer	Fluxgate

In this report only the results obtained from the measurements by space craft will be mentioned, whereas the numerous other sources of information about the solar corpuscular radiation (e.g. observations of comets, of the refraction and scintillation of radio sources, of the propagation and modulation of energetic particles) will not be discussed here. This material would go beyond the scope of Commission 44. It is anticipated that some of these results and also the theoretical interpretation of all observations will be included in the reports of the other relevant commissions.

Although some results will be mentioned which have already been obtained before the dateline of the last draft report, this summary will concentrate on the data given in publications between 1964 and 1966. Furthermore we shall review only the observations obtained in the interplanetary space. Nothing will be said about the most interesting phenomena related to the interaction of the solar wind with the magnetosphere.

2. *Observations of the particle flux*

2.1 *General remarks*

The solar corpuscular radiation has been investigated by means of space vehicles with plasma probes for measuring primarily the ion component, although some of these are able to detect also electrons. The expected mass motions should be more easily detectable from ion measurements, since the thermal motion of the ions is much smaller than that of the electrons assuming equal temperatures for both components.

Two different kinds of plasma probes have flown in space vehicles. One is a plasma cup which is used essentially as an integral analyzer for the energy with a wide angle of acceptance for the arriving particles. Such instruments have been developed by the group at MIT (Binnetti, Bridge *et al.* (**1**)) and flown first in Explorer X and later in several other satellites and space probes. Similar devices called ion traps have been used in Russian spacecraft (Gringauz *et al.* (**2–4**)).

The other type is an electrostatic analyzer used as a differential analyzer for the energies with a narrow angle of acceptance. Such an instrument was first used by the Jet Propulsion Laboratory group on board of Mariner 2 (Neugebauer *et al.* (**5**)) and later in other spacecraft by the Ames Research Center group (Wolfe *et al.* (**6**)) and by the Los Alamos group (Coon (**7**)).

Until now the time resolution of most of the measuring instruments was rather low due to the instrumental, power or telemetry limitations. For instance for the plasma probe of MIT on board of IMP–1 a complete energy scan required 2·8 minutes and was repeated every 5·5 minutes. For the electrostatic analyzer of Ames Research Center on board of IMP–1 a complete process of data acquisition and readout for a complete cycle energy and angular scan required 5 minutes and 28 seconds. For the later spacecraft these times have been shortened, e.g. during real time tracking of the Vela-2 satellites the time required to acquire information for a complete energy spectrum and direction was 128 seconds. But because successive portions of the data are acquired at one-second intervals, a change in the character of the radiation can sometimes be sensed with one second time resolution.

Until recently the instruments were also very limited as far as measurements of the angular distribution of the distribution function are concerned. Thus the wide aperture ion traps on the Luniks, Explorer X, IMP–1 etc. obviously could not investigate details of the particle distribution, and the narrow aperture electrostatic analyzer in Mariner 2 was constrained to look only at the Sun. Similarly the analyzer on IMP–1 yielded only very crude angular distributions (i.e. three sectors in spacecraft longitude, essentially no resolution in spacecraft latitude).

The analyzers on OGO–1, Vela 2A, 2B, 3A, 3B, had a much better longitudinal resolution, but again the observed current represents an integral over the solar plasma direction of arrival

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with respect to the spacecraft latitude. The first experiment capable of obtaining the complete angular distribution of the solar wind is the Ames Research Center experiment on board of Pioneer 6.

These facts about the instruments so far used should be taken into account in the following discussion of the results.

The first measurements of the solar wind were carried out by Gringauz *et al.* (**2–4**) with Lunik 2 and 3 and with the first Russian Venus rocket and by Bonnetti, Bridge and co-workers with Explorer X. Gringauz measured a flux of about 10^8 particles cm^{-2} s^{-1}, which was confirmed by Bonnetti, Bridge and co-workers. The measurements of the latter group indicated a definite wind that came approximately from the Sun with a velocity of about 300 km s^{-1}.

At present we have measurements available from Mariner 2 (20 August–30 December 1962) (Neugebauer and Snyder (**8**)), IMP–1 (27 November 1964–middle of February 1965) (Bridge *et al.* (**9**), Wolfe *et al.* (**6**)), IMP–2 (4 October–6 October 1964) (Wolfe *et al.* **10**)), Mariner 4 (January–March 1965) (Bridge *et al.* (**9**)), Vela 2, and 3 (1964, 1965) (Coon (**7**), Hundhausen *et al.* (**11**), Strong *et al.* (**12**)), OGO–1 (Wolfe *et al.* (**10**)), Pioneer 6 (Wolfe *et al.* (**14**), Bridge *et al.* (**9**)) which cover longer periods. The principal results from these observations during the stated periods are the following.

2.2 *Velocity*

Mariner 2: The daily average velocity was 504 km s^{-1}, with the lowest value between 306 to 318 km s^{-1} and the highest value between 815 and 842 km s^{-1}. Several streams of hot, high velocity plasma were observed to recur at 27-day intervals. The quiet, between-stream, solar wind velocity was in the range of 320 to 340 km s^{-1}. The velocity was independent of the distance from the Sun between 0·7 and 1·0 A.U. (Neugebauer and Snyder (**8**)). The relationship between the plasma velocity v and the density sum of the planetary magnetic activity index ΣK_p can be expressed as follows: $v = (8{\cdot}44 \pm 0{\cdot}74)\, \Sigma K_p + (330 \pm 17)$ [km s^{-1}] (Snyder *et al.* (**15**)).

IMP–1: Average velocity 378 km s^{-1}, ranging from less than 300 to less than 570 km s^{-1} during relatively quiet periods. During disturbed times the velocity ranged from 560 to 750 km s^{-1}. The average direction of the ion flux coincided usually with the apparent direction from the Sun. The fluctuations in the arrived angle were about ± 15 degrees (Wolfe *et al.* (**6**)).

IMP–2: Velocity during geomagnetically disturbed periods 712 ± 13 km s^{-1} (Wolfe *et al.* (**10**)).

Mariner 4: Velocity between 275 km s^{-1} and 600 km s^{-1}. At the time of passing the planet Mars (15 July 1965) the velocity was 330 km s^{-1}.

Vela 2, *Vela* 3: Quiet solar wind velocity (derived from the minimum) 320–330 km s^{-1}. Usually the velocity is enhanced and variable, maximum velocity is 720 km s^{-1}, the peaks of the velocity generally recur at intervals of 27 days, persisting through several solar rotation periods. Direction varies over a range of about 15° (Coon (**7**)). At present some 12 000 individual measurements of the angle of arrival have been made from data obtained between July 1964, and July 1965 by the Vela 2 satellites. The average flow for these cases is from 2°6 east of the Sun (after correction for aberration due to the Earth's orbital motion) (Strong (**16**)).

Venus 3: Velocities in the range of 300 km s^{-1} to 415 km s^{-1} (Gringauz *et al* (**13**)).

Pioneer 6 (16 *December* 1965): Data not yet available. Flow direction has significant deviations from the nearly radial direction in the ecliptic plane and fluctuations as high as ± 5° are observed. Northerly as well as southerly flow with respect to the ecliptic plane has been observed while the flow direction during quiet times remained steady over periods of many hours. During periods apparently associated with solar and terrestrial disturbances, the flow direction toward much greater variability (Wolfe *et al.* (**14**)).

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2.3 *Density*

Mariner 2: Near 1 A.U. the average density was approximately 5 protons cm^{-3}. The density was usually highest at the leading or western edge of each stream, with a maximum value of 80 protons cm^{-3}. Otherwise the density varied inversely with the plasma velocity. The lowest values were between 0·081 and 0·094 protons cm^{-3}, the highest between 70 and 88 protons cm^{-3}. The density changed approximately as the inverse square of the distance (Neugebauer and Snyder (**8**)).

IMP–1: The density rarely exceeded 1 to 3 ions cm^{-3}, except in association with geomagnetic storms (Wolfe *et al.* (**6**)).

IMP–2: Density during geomagnetically disturbed period was $2{\cdot}46 \pm 0{\cdot}5$ protons cm^{-3} (Wolfe *et al.* (**10**)).

Vela 2, *Vela* 3: Typical ion densities were to 3 to 5 cm^{-3} (Coon (**7**)).

Venus 3: The ion density was within the limits of 2·4 cm^{-3} and 55 cm^{-3} (Gringauz *et al* (**13**)).

Pioneer 6: Data on the ion density not yet available. The electron density had been determined by a radio propagation experiment from Pioneer 6 and simultaneously by ionosphere measurements using signals from two Beacon satellites. The average interplanetary electron number density near the earth orbit was between 8 and 9 cm^{-3} in the time interval from 20 February to 9 April 1966.

2.4 *Temperature*

In most cases it is not easy to determine the temperature from the measured distribution function which is not really a Maxwellian distribution. Furthermore the later more refined measurements show that the temperature is not equal in different directions. Most of the early observations of the random motions were made from differential energy spectra reflecting the particle flux as a function of energy in some fixed directions. An alternate method of temperature determination involves the measurement of the particle flux in different directions. The width of the resulting 'angular distribution' is related to the ratio of the mean random velocity to the bulk velocity and hence to a 'temperature' in the direction normal to the bulk velocity.

Mariner 2: The high-velocity streams were hotter than the surrounding plasma. The average daily-average value of the proton temperatures T_p was between 1·51 and $1{\cdot}85 \times 10^5$ °K (on 17 December 1962), the minimum value was 3×10^4 °K for the end of the 'between-stream' periods. There was no obvious radial dependence (Neugebauer and Snyder (**8**)).

The energy density of proton random motions was never more than a small fraction of the energy density of bulk motion (in the average between 0·013 and 0·017, the maximum value was between 0·014 and 0·115, the actual minimum could not be determined). The spectra had usually high-energy tails which became more pronounced at the higher plasma velocities. It is not clear if these high energy tails are connected with the anisotropic distributions observed by Vela 3 and Pioneer 6.

IMP–2: The proton temperature was $2{\cdot}0 \pm 0{\cdot}5 \times 10^5$ °K. Ratio of thermal energy density to kinetic energy density was about 7×10^{-3} (Wolfe *et al.* (**10**)).

Vela 2, *Vela* 3: The proton temperatures in a transverse direction ranged from 8×10^5 °K. down to 6×10^3 °K. The low temperatures (typically near 2×10^4 °K) were observed when the solar wind velocity was high. During magnetically quiet periods, that is when K_p was low, the solar wind velocity was low (~ 325 km s^{-1}) and very steady, and the temperature was at the low end of its range, lying close to 10^4 °K. At the onset of a magnetically disturbed period within the magnetosphere (when K_p becomes high), the solar wind velocity rose as high as 700 km s^{-1} and the temperature above 10^5 °K (Coon (**7**), Strong *et al.* (**12**)).

The temperature in different directions could be investigated in more detail by Vela 3. The ion temperature was higher along the field ($T_{\|}$) than transverse to this direction ($T_{\perp}$) The most probable value of T_{max}/T_{av} found in the Vela 3 observations is 1·4; this corresponds to $T_{max}/T_{min} = 2$ for a symmetric distribution.

Pioneer 6: The ratio $K = T_{\|}/T_{\perp}$ is investigated in detail. On 26 December 1965, K was found to be 5 and the angle between the flow velocity and the magnetic field about 60°. This high value of K is not an isolated case. In the data thus far analyzed, the results imply that at times $T_{\|}$ may exceed $T_{\perp}$ by as much as one order of magnitude. $K = 5$ is a common situation. These anisotropies are higher than those measured by Vela 3. This difference may, however, not be real but caused by different techniques used to measure 'temperatures' (Wolfe *et al.* (**14**)).

2.5 *Composition*

Mariner 2: The ratio of α-particles to protons n_α/n_p was observed to be 0·046 ± 0·038. A model in which the protons and α-particles have equal thermal velocities gives a better fit to the observed spectra than does an equal temperature model (Neugebauer and Snyder (**8**)).

IMP–2: $n_\alpha/n_p \approx 0{\cdot}02$ (Wolfe *et al.* (**10**)).

Vela 2, *Vela* 3: The observations showed that the α-particle proportion is variable, from less than 1% up to ∼ 20%, and the estimated average was 3% to 6%. From Vela 3 observations it was found that the ratio of the number densities of the alphas and protons varied from 0·00 to 0·15 with a mean value of 0·042 (Coon (**7**), Hundhausen *et al.* (**11**)).

Pioneer 6: Here it was possible to detect a third ionic species, He^+. The following data for the composition were given for one date of observation (26 December 1965): $H^+ \sim 91{\cdot}3\%$, $He^{++} \sim 8{\cdot}6\%$ and $He^+ \sim 0{\cdot}1\%$. In the data analyzed so far the He^{++} and He^+ contents show a large variance being at times almost unobservable (Wolfe *et al.* (**14**)).

3. *Observations of the magnetic fields*

3.1 *General remarks*

The magnetic fields in the interplanetary space have been measured during the last years in great detail and accuracy. The time resolution of the measurements is in most cases higher than that of the plasma measurements. A number of different instruments have been used, like fluxgate magnetometers, search-coils, proton precession magnetometers, helium magnetometers and rubidian vapor magnetometers.

3.2 *Average field and its direction*

Even before the solar wind properties were determined, the interplanetary magnetic field was measured by Coleman *et al.* (**17, 18**) with Pioneer 5. More precise and long-term measurements have been made by Mariner 2, IMP–1, Mariner 4, IMP–3, and Pioneer 6 (Coleman *et al.* (**19, 20**), Ness (**21, 22, 23**)). Because the interplanetary field has an energy much smaller (∼ 1%) than the solar wind energy densities, it is carried along by the solar wind. Field values were usually between 2 and 7 gammas and averaged near 5 gammas. The field pointed roughly away from the Sun or towards the Sun with the theoretically expected angle associated with the Archimedian spiral angle.

3.3 *Origin of the field*

Ness and Wilcox (**24**) have investigated the origin of the interplanetary magnetic field. The direction of the field shows a strong recurrence tendency with an interval of 27 days which corresponds to the rotational period of the solar equatorial region as seen from the Earth and suggests a solar origin of the interplanetary field. A cross correlation function constructed for the IMP–1 data yields the result (Ness and Wilcox (**25**)) that the time of effects for a coherent peak is 4·5 days. This leads to an average plasma velocity of approximately 385 km s^{-1} reported by the MIT plasma experiment in IMP–1 for the same time interval.

The solar latitude of the regions that constitute the source of the interplanetary magnetic field has been investigated in terms of the solar rotation. As seen from the Earth, regions near the solar equator rotate with a period of about 27 days, whereas regions at high latitude have a slower rotation velocity, with a period of about 30 days. This study suggests that the latitude of the solar source was within 10 or 15 degrees of the center of the visible disk or of the equator.

3.4 *Sector structure and filaments*

The interplanetary magnetic field exhibited a well defined 27-day periodicity. This periodicity was interpreted as evidence for a connection between the field at 1 A.U. and the large-scale patterns in the solar magnetic field that were observed between August and November 1962 during the flight of Mariner 2 (Coleman *et al.* (**26**)). Two reversals of the polarity occurred during each of the solar rotations. These reversals occurred at the time of a local minimum of the plasma velocity and were followed within 2·5 days by a local maximum of the velocity.

The sector structure has been observed best between November 1963 and February 1964 during the flight of IMP–1 (Ness and Wilcox (**25**)). A correlation was established between the field pattern indicated by the IMP–1 data and patterns in the photospheric field. The interplanetary field was highly organized during this time on a 27-day basis into four segments within each of which the direction of the field was most of the time either positive or negative. Three sectors had a duration of 7.7 days, and one was 3·8 days long. There was a coherent variation of the interplanetary magnetic field strength with the planetary magnetic index K_p within each sector region and also a similar variation of the flux and the density throughout the sector structure.

During the flight of Mariner 4 (Coleman *et al.* (**26**)), one year later, the variation in the recorded field over 27-day periods showed much less of the well defined periodicity that characterized the earlier observations. It is suggested that the pattern becomes less stable after the minimum in the cycle of the solar activity, which occurred during the period from May through November 1964, and may well become still less regular as the Sun becomes more active.

Wilcox and Ness (**27**) have suggested that this sector structure may be an important aspect for the development of M-region type storms which have yet to be identified with some defined features on the surface of the Sun. The results of Mariner 2, IMP–1 and Mariner 4 support a model in which the high velocity streams in the solar wind originate in regions throughout which the magnetic field has a single polarity.

In this connection the earlier work by Babcock and Simpson (**28**) should be remembered, namely the relation of the 27-day recurring cosmic ray modulation with 'unipolar magnetic regions' on the Sun and M-region type geomagnetic storms.

In connection with the observed sector structure during the time of IMP–1 it is of interest that a recurring stream of protons of a few MeV energy is almost entirely contained within one sector (Fan *et al.* (**29**), and Bryant *et al.* (**30, 31, 32**)).

The collimation of solar cosmic rays with energies between 7·5 and 90 MeV has been increased during the flight of Pioneer 6 (McCracken *et al.* (**33**), and Bartley *et al.* (**34**)). For a certain period of a flare event (29 December 1965), the azimuth of the magnetic field vector and the azimuth of the cosmic ray anisotropy were highly correlated. Despite major changes in the interplanetary field direction, the cosmic ray anisotrophy remained well aligned with the field.

Also the measurements by Fan *et al.* (**35**) showed the collimation of cosmic ray particles by the magnetic fields. This group was able to prove that these particles were protons (not electrons) and that the largest effects extend down to 1 MeV energy.

From these and other measurements (Ness (**36**)) it is concluded that within the interplanetary medium numerous separate bundles of magnetic flux exist that are adjacent to and in equilibrium with each other. These separate bundles are convected outwards by the solar wind but still retain, in general, an Archimedian spiral configuration in the average, although the bundles are intertwined with each other.

Simultaneous observations of proton intensity-time distributions from Pioneer 6 and IMP–3 at Earth confirm that spatial features in the magnetic field with dimensions as small as 4×10^5 km persist for time intervals of at least two hours in which the magnetic field is in co-rotation with the Sun (Fan *et al.* (**35**)).

3.5 *Fluctuations*

Besides the measurements of the strength of the magnetic field and its direction it is important to show its variations in time and space. We know that the field fluctuations, and the measurements of the power spectra will give us indications about the kind of waves that are propagating and also about the instabilities which might be present influencing the particle distribution function. Also correlations between different locations in space are indicative for the propagation mechanism in the interplanetary space. Furthermore we expect not only small amplitude waves, but also those with large amplitudes and finally shock waves.

The problem of discontinuities in the solar wind has been in particular investigated by Colburn and Sonett (**37**). We refer to his recent excellent review paper, where many details can be found about the observations as well as about the theoretical aspects. Coleman (**38–40**) has studied the variations in the interplanetary magnetic field during the time of flight of Mariner 2. He obtained power spectra of the fluctuations for the total field as well as for the three components of the field. The power densities in the spectra are steeply decreasing functions of the frequency f with a dependence between f^{-1} and f^{-2} between 100 and 500 cycles per day. Coleman established also the existence of coherent variations in the field and in the radial component of the plasma velocity. The results suggested that the variations in the interplanetary field are predominantly changes in field orientation rather than in the strength of the field. This indicates that the oscillations are probably transverse waves.

A power spectrum of the fluctuating field has also been measured during the flight of OGO–1 and of Pioneer 6. It should be mentioned in this connection that from the IMP–1 data (Wolfe (**6**)) it is apparent that rapid (period less than 5 minutes) small-amplitude fluctuations were always present in the velocity of the solar wind even during geomagnetically quiet periods. These fluctuations increased in amplitude, however, during geomagnetic storms.

The usefulness of simultaneous measurements of the interplanetary magnetic field has been demonstrated by Ness (**36**), who presented preliminary results obtained from Pioneer 6 and from IMP–3 at two separate points of observation during the same time at distances from 350 000 to 700 000 km from the Earth. The general similarity but time delayed feature of a reversal of the magnetic field when observed by the two satellites on opposite sides of the Earth and separated by $1{\cdot}3 \times 10^6$ km can be interpreted only in terms of the corotation of the interplanetary magnetic field structure. Radial propagation of the field reversal would lead to a time delay substantially less than five minutes, compared to the observed time delay of 57·5 minutes. In this connection also the observed large scale oscillations of proton intensity period of 10^3 s) should be mentioned (Fan *et al.* (**35**)).

Also Smith *et al.* (**41**) have carried out simultaneous measurements of the interplanetary magnetic field from OGO–1 and Mariner 4. Data were available during the intervals from 28 November to 11 December 1964 and from 8 March to 4 May 1965. During the first interval the separation between the two spacecraft increased from about 1/3 to 5 million km and during the second interval from 46 to 112 million km.

4. *Summary*

Summarizing all these measurements carried out so far the following can be said about the properties of the solar wind: The quiet solar wind velocity is of the order of 300–350 km s^{-1}

near the orbit of Earth with a direction almost away from the Sun (taking into account the appropriate correction for aberration due to the orbital motion of the Earth). Its density is of the order of 5 protons cm^{-3} and the temperature probably closer to 10^4 °K than to 10^5 °K. The temperature parallel to the magnetic field is higher than that transverse to the field, very often by a factor of five α-particles (He^{++}) amounting to about 5% in numbers of the protons and perhaps 0·1% of He^+.

The wind is highly variable in its velocity (up to about 850 km s^{-1}), in its direction ($\pm$ 15°), in its temperature (up to 9×10^5 °K), and in its composition (up to 20% α-particles). Often there exist streams of hot, high velocity plasma which recur at 27-day intervals. So far no measurements are available concerning the period of maximum solar activity.

The averaged magnetic field has a spiral structure with a strength of about 5 gammas. Very often it shows 27-day periodicity and a certain sector structure.

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APPENDIX I. INVESTIGATIONS OF INTERPLANETARY PLASMA IN THE U.S.S.R. IN 1965 AND 1966

(prepared by K. Gringauz)

In 1965 and 1966, theoretical and experimental studies of problems connected with interplanetary plasma were continued in the U.S.S.R.

E. R. Mustel has analysed the role of active regions of the Sun in production of quasi-stationary plasma flows in interplanetary space (1). Two hypotheses were considered. According to one of these hypotheses, quasi-stationary flows of solar corpuscles appear in the most active regions, and, according to the other, active regions only deflect fluxes generated in undisturbed regions of the Sun (hypothesis of the 'escape cone'). In (1) various observational results were used (data derived from direct measurement of fluxes of solar plasma and interplanetary magnetic fields as well as measurements of cosmic rays of solar origin, of radiowave absorption in auroral zones) and a conclusion was made that all data fully confirm the first hypothesis (of active regions).

Studies of statistical very rich results of magnetic measurements performed mainly by Mariner–2 and IMP–1 space probes, gave grounds to Yu. D. Kalinin and E. I. Mogilevsky for extension of a hypothesis on a 'plasmoid' macroscopic structure of corpuscular fluxes generated in active regions of the Sun (2). According to the above mentioned hypothesis, this flux consists of a chain of independent elements, each of which moves radially and possesses its own quasi-force-free magnetic field (satisfying the condition (rot **H**·**H**) = 0).

Each of these elements plasmoids (M-elements, according to the authors' terminology) retains the angular momentum of the Sun's rotation. Thus the whole chain is placed along Archimedes' spiral, the slope of whose tangent is determined by radial velocity. The dimensions of each M-element increase with time. The chain of the M-element is propagating in Parker's quiet solar wind.

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The above hypothesis seems to be of importance for elucidating the mechanisms of the appearance of disturbances in the Earth's magnetosphere.

Interesting data relating to interplanetary plasma are obtained during radioastronomical observations.

T. D. Antonova, V. V. Vitkevich and V. I. Vlasov (3) revealed the scintillation of source 3C 48 at a wavelength of 3·5 m with a period of 3 seconds determined by inhomogeneities of electron concentration in interplanetary plasma.

V. V. Vitkevich and V. I. Vlasov (4) reported the first results of the experiment on determining the velocity of motion of inhomogeneities in interplanetary plasma derived from data of synchronous observations of fluctuations in intensities of radioemission of sources 3C-144, 3C-43 and C3-147 at three points situated at apexes of an equilateral triangle with side of about 220 km.

For the observational period from July 1966 to August 1966 the greatest velocities were 350 km s^{-1}. At velocities of 220–350 km s^{-1}, the directions of velocities are close to the direction away from the Sun. The dispersion of directions was $\pm$ 30°. According to the authors, the characteristic size of inhomogeneities was about 400 km with dispersion by a factor of 1·5 to 2. The greater portion of inhomogeneities moves together with a common flux of solar plasma. On the average a direct correlation is observed between the dimensions of the inhomogeneities and their velocities.

The results of measuring the solar plasma fluxes (solar wind) were processed. The measurements were performed from Zond-2 by V. V. Bezrukikh, K. I. Gringauz *et al.* (5). Zond-2 carried both traps which recorded the integral flux of the solar wind ions and an ion trap of a modulation type oriented on the Sun which made it possible to obtain energy spectra of ions with energies of up to 3·6 keV. These experiments showed that the absence of geomagnetic disturbances corresponds to very small fluxes of solar wind ions ($\sim 2 \times 10^7$ cm^{-2} s^{-1}), while during geomagnetic storms ($K_p = 5$) fluxes of solar plasma ions near the Earth's orbit amount to 10^9 cm^{-2} s^{-1}. K. I. Gringauz, V. V. Bezrukikh and L. C. Musatov processed also the results of measurements of solar wind energy spectra performed by means of a sun-oriented ion modulation-type trap from Venus–3 at the close of 1965 and in early 1966 (6). These measurements have made it possible to draw the following basic conclusions:

In all cases, when the instrument for studying the solar wind was switched on, ion fluxes were registered. The total flux of ions with energies of about 3600 eV for a period from 16 November 1965 to 7 January 1966 was within the limits of $1{\cdot}5 \times 10^8$ cm^{-2} s^{-1} to 2×10^8 cm^{-2} s^{-1}. The velocities of the main (largest) components of the spectrum for this period did not exceed 510 km s^{-1}. Often the fluxes close by their magnitudes were recorded in different energy ranges (the width of each range was about 450 eV). In these cases the determination of some directed velocity characterizing the solar wind becomes difficult. It is possible that some spectra of this type correspond to the penetration of the fast solar plasma flux into one which moves slower. Although large ion fluxes ($N = 10^9$ cm^{-2} s^{-1}) most often correspond to high K_p-indexes, apparently one is unable to establish a correlation between some structural parameter of the undisturbed solar wind and the intensity of geomagnetic disturbances. It is possible, that geo-effectiveness of solar wind fluxes is greatly affected by the orientation of the vector of the interplanetary magnetic field in the vicinity of the Earth's magnetosphere.

Measurements of the solar plasma fluxes in the neighbourhood of the Moon performed by means of charged traps from Luna–10, the first artificial moon satellite, in April and May 1966, by Gringauz, Bezrukikh *et al.* (**7, 8**), have shown that near the Moon, there is a disturbed region in which plasma fluxes move in the direction differing from the direction of solar wind in undisturbed interplanetary space. Some signs were also revealed that, each month, the Moon in a period close to full moon, approximately for four days, is situated in the tail of the Earth's magnetosphere where undisturbed wind does not penetrate.

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APPENDIX II. INVESTIGATIONS OF NEUTRAL HYDROGEN IN THE REGION OF THE EARTH AND IN INTERPLANETARY SPACE

(prepared by V. G. Kurt)

During 1964–66 in the Soviet Union, investigations of scattered solar $L\alpha$ radiation were made with devices mounted on cosmic rockets.

V. G. Kurt and V. V. Katiushina carried out three experiments on the geophysical rockets. $L\alpha$ radiation and radiation in lines of the triplet O I $\lambda 1300$ Å were measured at the height up to 500 km (6 June 1963; 25 October 1963; 24 December 1963). During these experiments, the Sun was at the height of $+5°$, $+3°$ and $-17°$ above the horizon. The following data were obtained: on the distribution of hydrogen in the Earth's atmosphere, on its full contents and on the effect of the dependence of optical thickness on the solar zenith distance in the place of observations. With similar devices V. G. Kurt carried out observations of scattered $L\alpha$ radiation in the upper atmosphere of the Earth and in the interplanetary space. The observations were carried out from the board of automatic interplanetary station 'Zond–1' launched on 2 April 1964. These measurements showed that thickness of neutral hydrogen up to 6·5 terrestrial radii is equal to 20 cm^{-3} with $R = 42\,000$ km. The intensity of scattered radiation in interplanetary space is $1{\cdot}5 \times 10^{-4}$ erg cm^{-2} s^{-1} $ster^{-1}$ that corresponds to the concentration of interplanetary hydrogen $\sim 10^{-2}$ cm^{-3} with the temperature $\sim 10^5$ °K. More thorough investigations were carried out from the board of 'Venera–2' and 'Venera–3' 12 and 16 November 1965). The concentration of $L\alpha$ radiation to the plane of the ecliptic was not discovered. From these measurements, the concentration of hydrogen was determined up to 20 $R_{\oplus}$, equal on this distance to about 3 cm^{-3}. The upper limit of the intensity in the interval 1225–1340 Å, equal to about 10^{-24} w m^{-2} Hz^{-1} $ster^{-1}$ (3×10^{-7} erg cm^{-2} s^{-1} $ster^{-1}$) was determined.

V. V. Katiushina solved the problem of the scattering of the radiation in the lines O I $\lambda 1300$ Å in the Earth atmosphere, taking into account the absorption by the molecular oxygen in the coherent approximation.

S. A. Kaplan and V. G. Kurt constructed an approximated theory of $L\alpha$ radiation transfer in the spherical atmosphere taking into account the Earth's shadow. They also explained the character of transfer of the radiation in lines O I $\lambda 1300$ Å in the flat atmosphere without taking into consideration redistribution according to frequencies.

T. A. Germogenova solved the problem of the diffusion of $L\alpha$ quanta in the zone H I taking into consideration zone H II in the assumption of coherency using this calculation.

KK2

V. G. Kurt and T. A. Germogenova obtained the lower limit of the dimension of the zone H II near the Sun, as equal to $10^3 - 10^4$ A.U. They showed that $L\alpha$ radiation observed in the solar system cannot be completely explained by terms of the scattering on cold galactic hydrogen. The whole effect is explained by hot ($T \sim 10^5 - 10^6$ °K) interplanetary hydrogen with the concentration 10^{-2} to 10^{-3} cm^{-3}.

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APPENDIX III. SKY LUMINOSITY IN THE ULTRAVIOLET REGION OF THE SPECTRUM

(prepared by A. B. Severny)

Sky luminosity in the ultraviolet region of the spectrum ($\lambda = 2800$ Å) was measured with the astrophotometer (AF–3) supplied with two photomultipliers: 57 for the measurings in the ultraviolet region and 15 – for the measurings in the visible region. The device was mounted on the satellite 'Cosmos–51' launched on 10 December 1964. The device operated during three months on the heights about 300 km.

The following results were obtained:

The lowest sky luminosity in the ultraviolet region is approximately equal to the luminosity of 190 stars of 10^m per square degree. This luminosity exceeds 2 to 3 times the expected luminosity of these stars derived from their energy distribution along the spectrum. Considerable fluctuations were observed of the ratio of the luminosity in the visible region to the luminosity in the ultraviolet as well as a discrepancy with the value of this ratio obtained from theory.

APPENDIX IV. DETERMINATION OF SPATIAL DENSITY OF METEORIC DUST IN SPACE

(prepared by T. N. Nazarova)

During 1963–66, measurements were conducted to continue the work aimed for determining spatial density of meteoritic dust in space. Data were obtained along the flight trajectories of the probes in the direction away from the Earth's orbit towards the Sun and away from the Sun and in the vicinity of the Moon.

From the experiments performed during the above-mentioned period and earlier, a conclusion may be drawn that non-uniformity in the distribution of meteoritic matter in space is rather the rule than the exception.

Apparently meteoric matter is united in space into more or less dense formations with linear dimensions varying within wide limits.

During the experiment with Luna 10 satellite, aggregations of particles were recorded in the vicinity of the Moon.

Note—Addenda to this Report of Commission 44 will appear in Volume XIII B of the *Transactions of the IAU*.

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