STUDY OF COSMIC RAYS WITH EARTH SATELLITES*

TILL last century science had but two sources from which it could obtain information on outer space, stars, nebulæ and planets. The first source was light radiated by heavenly bodies, and the second was meteorites. They were the only heralds of outer space known to science, that came to Earth. Early in our century, scientists discovered that an endless stream of invisible and intangible rays was pouring down on the Earth from cosmic space, and they were called cosmic rays. It was established that these rays were fluxes of electrically-charged particles possessing very high energy. Later it was found that the rays discovered are not strictly speaking cosmic rays, but arise in the Earth's atmosphere under the action of particles which have really come from the interior of outer space and were called primary cosmic rays. Since the interaction of primary rays and atmospheric matter takes place at very great altitudes, scientists had to confine themselves for a long time to the study of secondary rays. These studies resulted in highly important discoveries in atomic physics.

The nature of the primary cosmic rays, their composition, that is the atomic particles of which they are composed, how they have been accelerated to tremendous energies, and, finally, where they originate, are of enormous interest for contemporary physics and astronomy. When the answer to these and many other questions relating to the nature of cosmic rays has been found, science will be able to throw light on a great many important problems of natural science required for an understanding of the processes taking place on the surface of stars and phenomena in interstellar space.

Study of the primary cosmic rays helps to solve too, a number of geophysical problems, such as the investigation of structure of the outer parts of our planet's magnetic field which are inaccessible to us.

However, to study the primary cosmic rays, experiments have to be conducted in the upper atmosphere. Until recently, these experiments were conducted by taking up recording instruments in balloons or rockets, but the achievements of Soviet science and engineering have made it possible to use an incomparably better means for the purpose, namely, artificial Earth satellites.

The first study of cosmic rays under such conditions was made on Sputnik-2. Two particle counters installed on the Sputnik made it possible to measure the full flux of cosmic rays at various altitudes above the Earth and over different areas of our planet.

The main purpose of these experiments was to determine how the streams of rays differ from one another in different latitudes and how the stream changes in time, in other words, to study the so-called variations of cosmic-radiation intensity.

A study of the variations is very important for understanding the nature of these rays and flux of particles emitted by the Sun, streams, which serve as the original cause of magnetic storms on the Earth.

It should be mentioned that fluctuations in the number of particles in the flux are found also on the Earth's surface, but these are variations of secondary radiation, very often depending not on the changes in the stream of primary particles, but on meteorological conditions, that is, how dense the atmosphere is at a particular moment and hence also how many atoms happened to be in the way of the primary rays. Besides, primary particles possessing low energy (it is their number which is subject to the greatest fluctuations) produces practically no "offspring", that is, secondary rays which reach the Earth's surface.

What new data on cosmic rays have been obtained by means of the Sputnik?

It has been established that between the altitude of the order of 200 kilometres (Sputnik-2's lowest altitude above the Earth) and the altitude of 700 kilometres the intensity of the stream of primary cosmic particles increases roughly 40%, while measurements made earlier by means of balloons and rockets showed that from an altitude of 40 kilometres and higher the intensity remains approximately constant.

Is there any contradiction here or not?

The increased number of particles at high altitudes can be thoroughly explained. There are two reasons for it. The stream of cosmic rays comes to the Earth uniformly from all around. However, since particles which possess even the highest energies cannot penetrate the Earth, measurements near the surface

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of the planet register only the rays which come from above. As the measuring instrument is taken up higher and higher, it leaves so to speak the globe's shadow, registering an ever larger part of the stream. Obviously, at a very considerable distance from the Earth, it will record a stream approximately twice as intense as on the surface. At an altitude of 700 kilometres 15% more particles pass through the instrument as a result of this phenomenon.

The remaining some 25% of the increase are due to the fact that the higher the altitude the lesser the Earth's magnetic field.

Charged particles, as we know, get deflected in their path in the presence of a magnetic field and the deflection is more when the energy of the particle is low and increases with the intensity of the magnetic field. In this sense the Earth's magnetic field can be compared to an armour. Particles possessing low energy are almost immediately thrown aside, and particles possessing higher energy penetrate deeper into it. Obviously the higher the instrument is taken up, the more particles should it register.

As a result of the experiments conducted on Sputnik-2 data were obtained on the distribution of particle flux above the Earth, that is, how the intensity of their flux depends on the latitude and longitude. This distribution too is the result of the interaction of the particles with the Earth's magnetic field. The field tends to deflect the incident particles in the direction of its poles. The existence of this phenomenon was obvious from theoretical reasons, and were corroborated experimentally.

The Sputnik, however, enabled us to get a somewhat different picture. Its counters showed that the particles are distributed by the magnetic field differently from what had been imagined earlier, and we may draw the conclusion that the Earth's magnetic field is responsible for it, as the structure of its upper regions is different from the way it was presented by the theory based on ground measurements.

The experiments on the distribution of the intensity of the cosmic rays over the whole globe conducted on Sputnik-2 are but the beginning of extensive studies of the structure of the Earth's magnetic field. Many careful measurements with the aid of sputniks will be required before the accumulated data permit us to make definite and reliable scientific deductions.

One of the assignments of the equipment on Sputnik-3 is to continue the study of the intensity of cosmic rays.

It was stated in the announcement on the launching of Sputnik-3 that it is equipped also with the instruments for registering the high-energy photons and heavy nuclei.

What is the purpose of these measurements?

Scientists assume that the Sun, in addition to radiating intensive corpuscular streams and cosmic rays, from time to time emits waves akin to visible light but much shorter, or, as they say, hard electromagnetic radiation, also called high-energy photons or gamma quanta.

High-energy photons, like primary cosmic rays, do not penetrate the atmosphere all the way down to the surface of our planet, and scientists using ground equipment can therefore neither confirm nor deny this assumption with full assurance. Balloons and rockets are of no substantial help in solving this problem; it can be cleared up only by means of an artificial satellite.

Today it is evidently premature to say what the acceptance or rejection of this hypothesis will mean to science, but at any rate our concepts of the Sun and its activity will become more complete. If it is found that our luminary radiates high energy photons, a very alluring prospect may open up to astronomy, the prospect of studying heavenly bodies not only in the rays of visible light and with the aid of the radio waves recently "mastered" by astronomers, but also of using high-energy photons for their purposes.

Sputnik-3 will study still another problem relating to the physics of cosmic rays, namely, it will register the presence of heavy atomic nuclei in these rays.

It is very important for science, chiefly for astrophysics, to know what atomic nuclei go to compose the primary cosmic rays and the sort of nuclei they contain. Data on this could tell us a great deal about the origin of cosmic rays.

Only by getting the proper instrument up to a considerable altitude will we be able to get an answer to this question. We have already mentioned that on the whole all primary rays are absorbed in the upper layers of the atmosphere. It may be added that the heavier the nucleus the greater the probability of its being absorbed, and the shorter the path it travels in the atmosphere, and, hence, the higher must be the instrument to make it possible to register heavy nuclei.

For this purpose up to now science has had a more or less clear idea of the number of light nuclei which are a component part of cosmic streams. The "variety" of nuclei has been ascertained: it makes up roughly a quarter of Mendeleyev's table of elements. So far we have no information on the number of the heavier nuclei, but the studies by Sputnik-3 will enable us to throw light on this important problem too.

The launching of the third artificial Earth's satellite equipped with instruments to conduct all-round studies of cosmic space will further the progress made by means of the first sputniks and will provide science with many new data.

GEOCHEMICAL SURVEY TECHNIQUES

GEOCHEMICAL methods of mineral exploration are based on the premise that diagnostic disturbances in the normal distribution pattern of chemical elements may exist in accessible material in the vicinity of concealed ore deposits. Such geochemical anomalies result from the natural dispersion of elements from the site of the parent deposit and are commonly sought by the systematic sampling and analysis of rock, soil, vegetation, stream water and stream alluvium.

Geochemical dispersion patterns are subdivided into two genetic categories, namely, primary dispersions formed in depth at the time of mineralization, and secondary dispersions, which are usually formed in the zone of weathering. Primary dispersion patterns may occur as regional variations in the trace element content of rocks and minerals, associated with metallogenic provinces, aureoles of impregnation in the wall-rocks surrounding individual deposits, or 'leakage' dispersions of trace metals in the channel-ways followed by mineralizing solutions. In all cases, the primary dispersion is genetically related to the ore-forming processes. The interpretation of the geochemical anomalies in terms of the location of possible associated deposits is often difficult and is dependent on the understanding of the local geology. Secondary dispersions, on the other hand, are usually associated with the weathering cycle, and although the dispersion processes are complex, considerable progress has been made in the development and application of techniques having a proved practical value in prospecting. This is particularly true of geochemical soil surveys in areas of residual overburden, where the methods have been successfully used for detecting the presence of sub-outcropping deposits of copper, nickel, arsenic, gold, antimony, chromium, tin, tungsten, molybdenum and other metals.

At times, positive results have been obtained where copper, lead and zinc mineralizations have been concealed by transported glacial cover up to some tens of feet thick. Here, the metals have had the opportunity of migrating upwards into the overlying material by diffusion and other processes, including the growth of vegetation which has extracted the ore metals as part of its nutrient uptake. Although the systematic analysis of the plants themselves has been employed on occasions, it is normally found more practicable to sample the underlying soil wherein metal has accumulated over generations, in the biogeochemical cycle. Geochemical soil and vegetation anomalies are usually restricted to the immediate vicinity of the parent mineral deposit, but abnormal concentrations of metal may sometimes be detected in the surface drainage system up to several miles downstream from mineralization. Where such geochemical dispersion does exist, the systematic sampling of stream-water or alluvium may constitute a useful aid in the rapid mineral reconnaissance of comparatively large areas. Sampling and analysis of stream alluvium for metals extractable at normal temperatures have given particularly encouraging results in reconnaissance for copper and base metal deposits.

The practical application of geochemical methods has been made possible only by the development of extremely rapid, simple tests and there are now trace analytical techniques for a wide range of metals capable of being performed with adequate accuracy by semi-skilled personnel. For the most part, these tests are simplified versions of classical colorimetric and chromatographic methods, although spectrographic, fluorimetric and other procedures may be utilized for particular problems.

Current research is active and aimed at broadening the scope of existing methods, extending knowledge of dispersion processes, investigating the regional approach to comprehensive geochemical reconnaissance and developing appropriate analytical techniques. Progress in the application of geochemical techniques indicates that, when used in conjunction with geological, geophysical and other sources of information, they will play an increasingly greater part in modern mineral exploration.

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