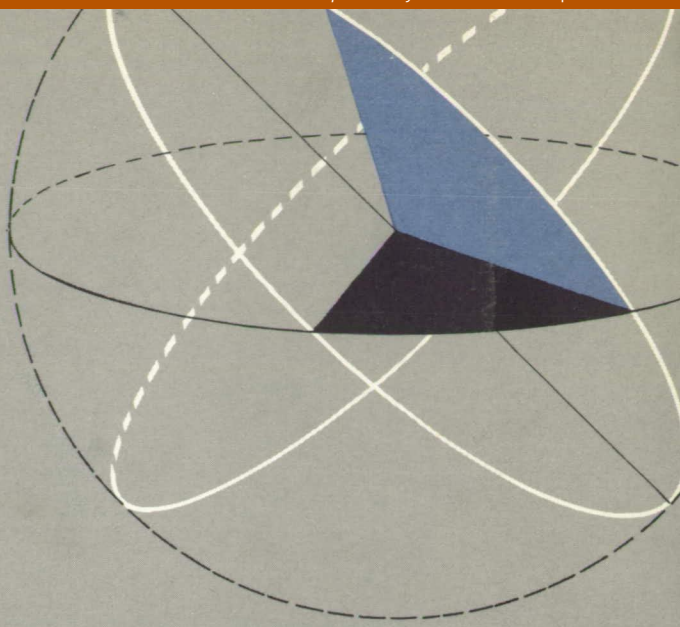
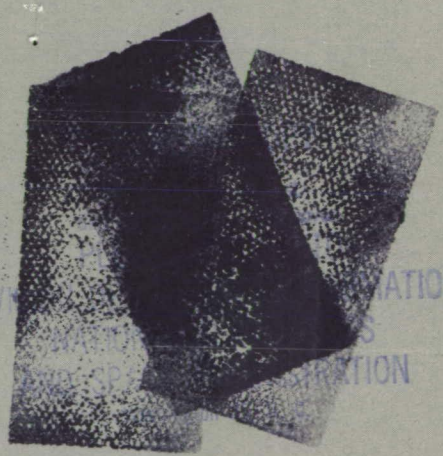
ASTRONAUTICS
INFORMATION



TRANSLATION NO. 13
THE EARTH'S CORONA



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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

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THE EARTH'S CORONA

Pravda, May 25, 1960

I. Shklovsky
Doctor of Physical-Mathematical Sciences

Translated by Joseph L. Zygielbaum

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California Institute of Technology
Pasadena, California
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CONTENTS

I. Along Future Cosmic Routes 1

II. Does Interplanetary Gas Exist? 2

III. Traps for Charged Particles 4

IV. Two Basic Conclusions 6

V. Hydrogen Atoms Leave the Atmosphere 8

FIGURES

1. Trap for Charged Particles 10

2. Dependence of Ion Concentration on Distance (from Earth's Surface) 11

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I. ALONG FUTURE COSMIC ROUTES

Many people believe that interplanetary space represents an absolute vacuum--actually it is not so--interplanetary space is filled with matter which is in an extraordinarily rarefied state.

A comprehensive study of the nature of the matter found in the uppermost layers of the Earth's atmosphere, and in interplanetary space, is one of the acute problems of today's astronomy and geophysics. Through the regions of cosmic space which are adjacent to our Earth pass the routes of our interplanetary flights of the near future. Just as in the case of aviation where it is necessary to know all properties of the aerial ocean surrounding the Earth, so also in the case of astronautics is it necessary to know all properties of interplanetary matter. This information is particularly important in securing reliable radio communication with interplanetary rockets.

There is also another no less important side to this problem. It is well known that through the interplanetary space there flow solar corpuscular currents, which after falling into the upper layers of the Earth's atmosphere cause considerable perturbations. It is this phenomenon in particular which determines the conditions

for our short-wave radio communication. Consequently, the study of the sources causing such perturbations and possibly their prediction is of great practical value.

Only after clarification of the properties of corpuscular solar fluxes and the interplanetary gaseous matter through which these fluxes travel is it possible to realize the nature of the great influence the Sun has on the various terrestrial phenomena. In this respect, astronomical and geophysical investigations, conducted over a period of many years from the Earth's surface have led to a clear understanding of the properties of the gaseous matter which prevails in cosmic space in the vicinity of as well as at large distances from the Earth. It is also true that very little is known about the nature of solar corpuscular fluxes. Such an abnormal situation is explained by the great difficulties with which one is faced during the solution of this interesting and important problem.

II. DOES INTERPLANETARY GAS EXIST ?

There are strong reasons to assume that in interplanetary space the gas should be prevailingly ionized; that is, it should consist of particles which are charged positively (ions) and negatively (electrons). In principle, the interplanetary ionized gaseous matter may be observed because the electrons which are part of its contents disperse solar light. Light rays, thereby, are subjected to determined qualitative changes, which are called polarization. On the other hand, interplanetary space is filled with almost imperceptible solid particles or dust, which also disperse solar light. This glow can be best observed in the morning and evening in the southern latitudes in the form of a bright gradually narrowing belt in the sky. The described phenomenon has been known for many centuries and is called "zodiacal

light." In comparatively recent times, German investigators have discovered a considerable degree of polarization of the zodiacal light. Based on this observation, they concluded that ionized gas is present in interplanetary space and, according to their measurements, at a distance of several million kilometers from the Earth's surface the number of particles of this gas per cubic centimeter is about 1,000.

This possible effect, as well as the observed polarization of the zodiacal light, may appear also during the dispersion of interplanetary dust. This fact was pointed out by Soviet and foreign astronomers, particularly the Academician, V. G. Fesenkov.

Peculiarities in the propagation of low-frequency impulses of radio energy, which are associated with lightning discharges, also testify to the fact that ionized gas is present in interplanetary space. By spreading along the lines of force of the Earth's magnetic field, such impulses pass through regions which are located at distances of 20,000 to 30,000 km from the Earth's surface, after which they again return toward the Earth's surface. However, the ionized matter through which such impulses pass could have been the outermost rarefied layers of the Earth's atmosphere rather than interplanetary gas.

In 1957 American scientists had, with the help of rockets, discovered an intensive night-time glow at high altitudes with an ultraviolet line of hydrogen "Lyman-Alpha." (Such radiation does not reach the surface of the Earth because it is already absorbed at an altitude of about 70 km.) The American scientists have attempted to explain this glow of the night sky with the dispersion of solar ultraviolet radiation by interplanetary atoms of hydrogen (non-ionized). Based on such a hypothesis, it would have been possible to evaluate the density of hydrogen atoms in interplanetary space, and thereby, by means of simple theoretical reason, to

calculate the density of ionized interplanetary hydrogen, which is the basic component of interplanetary gas. However, in 1958 the author of this paper had proved that the observed ultraviolet glow of the night sky can also be explained by the dispersion of ultraviolet radiation of the Sun along a very extended cloud of hydrogen atoms surrounding the Earth.

The well-known English geophysicist Chapman considers that the uppermost layers of the solar atmosphere, the so-called "Solar Corona," extends to such high altitudes from the solar surface that it reaches the Earth's orbit. According to this scientist, "We live in the Solar Corona." If Chapman is right, then a considerably large amount of ionized gas would be present in interplanetary space. Entirely contrary viewpoints have also been expressed. For instance, the well-known German astrophysicist Birman has raised several serious theoretical objections against the very possibility of the existence of gas in interplanetary space.

In conclusion, it should be said that the important problem of the existence of gas and its properties was completely unresolved until very recent times. No matter how paradoxical it may sound, astronomers have known infinitely more of the nature of interastral gas than of interplanetary gas. In recent times it became more and more evident that only a direct experiment in cosmic space will permit a solution of the question of the properties and the very existence of interplanetary gas.

III. TRAPS FOR CHARGED PARTICLES

All three Soviet cosmic rockets have made tests in the study of ionized gas in interplanetary space and in the uppermost regions of the Earth's atmosphere. These experiments were conducted by a group of Soviet radio physicists under the leadership

of Doctor of Technical Sciences K. I. Grinhauz. For this purpose special instruments (trielectrode traps for charged particles) were designed. A group of astrophysicists participated under the leadership of the author of this paper in the processing and explanation of a part of the very broad material obtained from this experiment.

The construction of the traps for charged particles is simple. (See Fig. 1). Isolated from the rocket's body, each trap consists of a small metallic plate (collector) and two screens. Charged particles drop on the collector and cause a negative electrical current in the case of electrons and a positive current in the case of ions. The magnitude of that current is measured with a special amplifier. In respect to the body of the rocket, the internal screen is negatively charged at 200 volts. This is necessary for the elimination of a photoelectron current which occurs as a result of the elimination by the collector of that part of the ultraviolet solar rays which does not reach the Earth's surface. Thanks to this internal screen, all electrons which are "pulled away" from the surface of the collector by the ultraviolet solar radiation return to the collector. A second screen is slightly charged in regard to the body of the rocket for the purpose of sorting out the particles according to energy.

On the Soviet cosmic rocket launched on September 12, 1959, four traps were installed with various potentials of external screens: +15, 0, -5, and -10 volts. As has already been indicated, positive current could have been caused only by ions; thus, their energy might be evaluated by comparing the readings of all traps. If all traps should simultaneously register negative current, it would indicate that the current was caused by fluxes of electrons. In this case, the energy of each electron would

exceed 200 electron volts since only such electrons are capable of penetrating through the retarding potential which is fed to the internal screen of the trap.

Information on the magnitudes and directions of fluxes in all traps was transmitted to Earth by means of telemetry systems. According to the measured values of the fluxes in the traps, taking into consideration all circumstances of the experiment, it was possible to determine the concentration of charged particles in the cosmic space surrounding the rocket, that is, the number of such particles per cubic centimeter.

As a result of measurements obtained by three Soviet rockets with the help of these traps, a huge amount of experimental data was obtained. During only one flight of a Soviet cosmic rocket in September of 1959 about 12,000 measurements of trap fluxes were transmitted to Earth.

IV. TWO BASIC CONCLUSIONS

Two basic scientific results of investigations with the help of traps are of concern here. Figure 2 is a graph showing the dependence of ion concentration on distance. The distance from the surface of the Earth is given in kilometers. Two conclusions may be drawn from this diagram.

First, the Earth is surrounded by a very extensive and rarefied atmosphere which consists of ionized gas. This atmosphere may rightly be called "the Earth's corona" or the "geo-corona." The concentration of ions in that geo-corona is on the order of several hundred positively charged particles per ccm. For comparison, one may say that a concentration of ions of the Earth's atmosphere at an altitude of about

300 km reaches 1 to 2 million per ccm. Near the Earth's surface the concentration of atmospheric molecules is expressed by a colossal 20-digit number.

From the character of the variation of ion concentration with distance from the surface of the Earth it is possible to draw a conclusion that the geo-corona consists of hydrogen. The geo-corona can be traced up to a distance of 22,000 km from the Earth's surface. There is, however, a basis to assume that the extent of the geo-corona is of a variable magnitude. That extent can depend on a number of circumstances, mainly on solar activity.

Second, in interplanetary space, at distances which surpass 22,000 km from the Earth's surface, a measurable concentration of ionized gas was not discovered. Therefore, considering the accuracy of the experiment, it is possible to make a conclusion that if in interplanetary space ionized gas exists its concentration is considerably less than several tens of ions per ccm. According to available indirect data based on an analysis of trap currents, the concentration of interplanetary ionized gas should be even much less than the mentioned value.

These experiments fully justify the assumption that there is no stationary ionized gas in interplanetary space. We underline the word "stationary" because at times, particularly during the periods of high solar activities, interplanetary space is filled with fluxes of high-speed charged particles. Obviously these corpuscular fluxes continuously "sweep out" the ionized gas from interplanetary space, which also is the reason for its absence during that period.

As a result of experiments with traps of charged particles the question on the nature of interplanetary matter was clarified considerably. A number of old beliefs should necessarily be dropped since they do not agree with reality. At the same time

these experiments have permitted for the first time a direct proof of the presence of an extended gaseous blanket-corona around our planet.

V. HYDROGEN ATOMS LEAVE THE ATMOSPHERE

Naturally, the question arises: Why is the Earth surrounded by a very extended hydrogen corona? Even if the entire theory of this interesting phenomena is as yet still not worked out, the explanation can be reduced in general terms to the following.

In the lower layers of the Earth's atmosphere there exist continuous water vapors. At altitudes exceeding 100 km, the ultraviolet radiation of the Sun decomposes the molecules of water and their component atoms of hydrogen and oxygen. Up to an altitude of 130 to 160 km the Earth's atmosphere is well stirred up, and therefore the corresponding part of hydrogen atoms remains more or less constant. In higher altitudes atmospheric stirring ceases, however, and lighter hydrogen atoms increase in number with the increase of altitude. At an altitude of from 1500 to 2000 km the hydrogen in the Earth's atmosphere becomes the basic element. It should be mentioned that the velocities of thermal movements of hydrogen atoms are sufficiently large that a considerable number of these velocities exceeds the first cosmic velocity. Thus, the atoms of hydrogen present in the uppermost layers of the atmosphere are continuously leaving that atmosphere and disappearing into interplanetary space. This continuous disappearance of hydrogen atoms beyond the realms of the Earth creates the geo-corona.

If it weren't for the continuous replenishment of hydrogen by the vaporization of water from the oceans, the entire supply of hydrogen which is present in the Earth's

atmosphere would have disappeared into interplanetary space. Calculations indicate that for this reason the level of the world's oceans has decreased by several meters during the entire geological history of the Earth.

Thus, already the first experiments on direct "sounding" of the gaseous environment in cosmic space have yielded very valuable scientific results. In this paper only a few of the problems have been considered. For instance, a question not touched upon is that of the currents of solar charged corpuscles discovered with the help of traps at distances of hundreds of thousands of km from the Earth, where its magnetic field becomes insignificant. The processing of results from measurements of the trap fluxes, however, has pinpointed the properties of the radiation belts. The complete results of the investigations, which were accomplished with the help of traps of charged particles, are being published in Soviet scientific journals.

There is a basis to assume that further sounding of cosmic space will yield a great number of new valuable scientitic results.

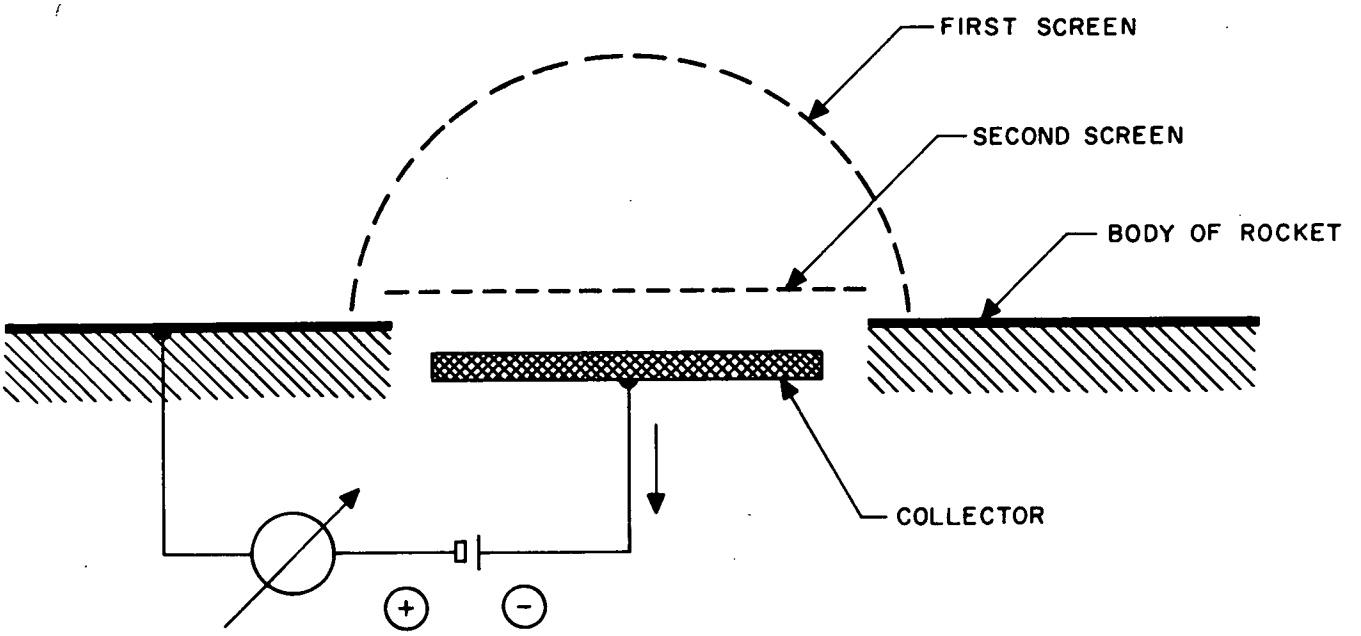

Fig. 1. Trap for Charged Particles

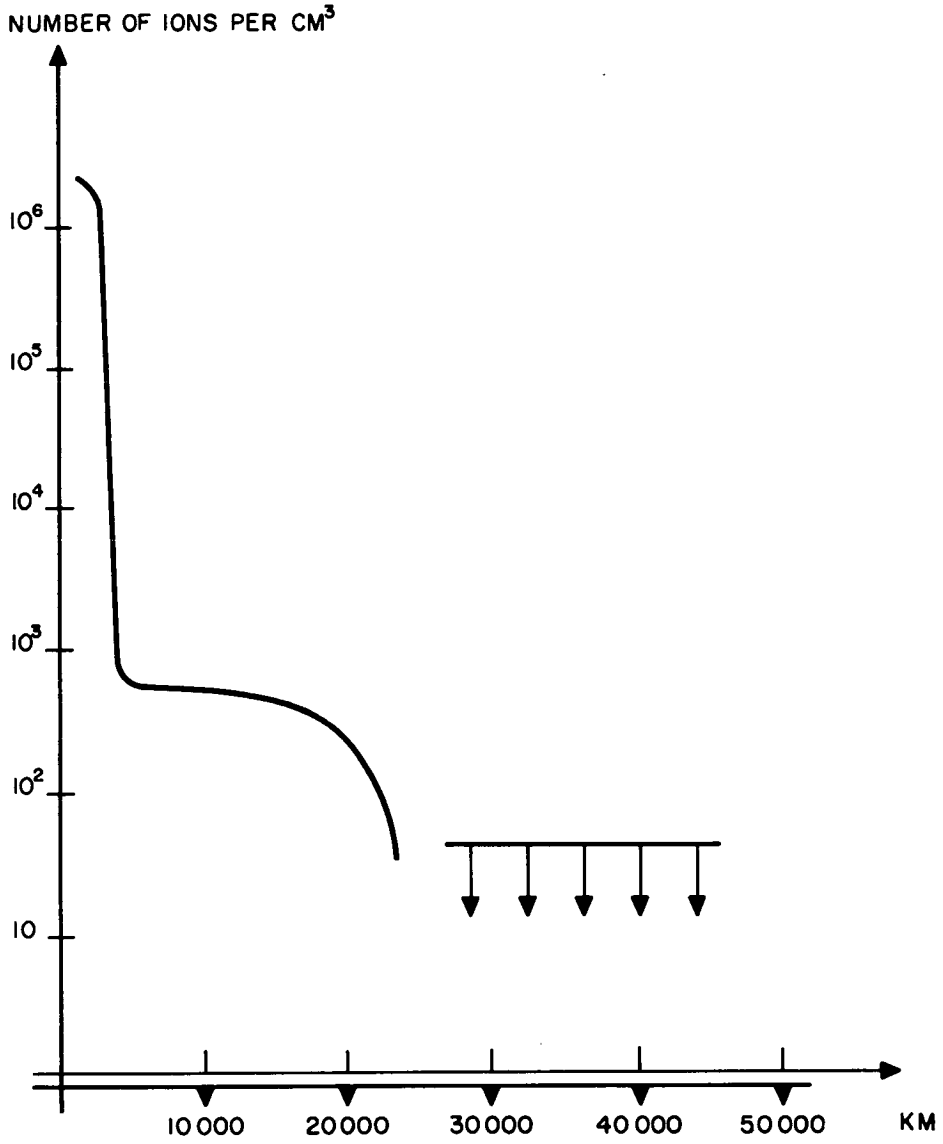

Fig. 2. Dependence of Ion Concentration on Distance (from Earth's Surface)