SCIENTIFIC SESSION OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY OF THE USSR ACADEMY OF SCIENCES

(September 30 to October 1, 1970)

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ON September 30 and October 1, 1970 the scientific session of the Division of General Physics and Astronomy was held in the conference hall of the Lebedev Physics Institute of the USSR Academy of Sciences. At the session the following reports were heard:

1. S. B. Pikel'ner, Magnetic Hydrodynamics of Solar Formations.
2. V. L. Ginzburg, Pulsars—Present State of the Problem.
3. Ya. G. Dorfman, New Results from the Study of the Plato's Physics.
4. I. D. Rozhanskiĭ, On the Question of the Rise of Atomic Theory in Antiquity.
5. D. A. Varshalovich and M. I. D'yakonov, Quantum Theory of the Modulation of an Electron Beam at Optical Frequencies.

The contents of the reports read are printed below in brief.

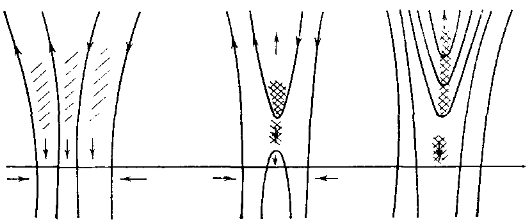
S. B. Pikel'ner, Magnetic Hydrodynamics of Solar Formations.

The greater part of phenomena observed on the surface of the sun—spots, faculae, flocculi, solar prominences, flashes, the fine structure of the chromosphere—are connected in one way or another with the influence of a magnetic field. The source of the surplus luminous energy of the upper photosphere and chromosphere of the active regions is the amplification of convection caused by the fact that the field suppresses turbulence and reduces turbulent viscosity. The flashes occur in the neutral surfaces of the strong magnetic field, where annihilation of magnetic energy occurs. In all these problems an essential role is played by the construction of an adequate model of the phenomenon. The prominences and the fine structure of the chromosphere, i.e. the spicules and filaments, are examined in detail.

The prominences constitute thin layers of dense gas that are suspended vertically. This gas is supported by a magnetic field, the most probable model of which resembles an arch with a depression at the top. In order that the prominence be stable, this depression must exist also without the weight of a heavy gas. The cause of the formation of the prominence and the cause of its condensation constitute the basic question. It is usually supposed that this is connected with thermal instability and with an inverse dependence of the radiation power of the corona gas on the temperature. However, thermal instability would lead to the disintegration of the corona into two gases and to the appearance of condensations everywhere, whereas prominences are formed in definite field configurations and their mass is comparable with the mass of the whole corona. Another hypothesis, compression of the gas by magnetic forces, does not agree with the structure of the fields and with the fact that the gas flows downward from quiet prominences and does not rise upward. Here it is shown that the appearance of an arch with a depressed peak must automatically lead to the formation of a prominence. The corona is heated by the stream of magnetoacoustic and magnetohydrodynamic waves coming from below. These waves do not pass into the depression, the accelerated ones because of strong refraction, and the decelerated and Alfven ones because they do not spread across the lines of force. For this reason the gas in the depression is cooled, its equilibrium is destroyed, and a current is started as in a siphon. The gas is pumped out of the chromosphere along the arch into the depression and there it condenses. Calculation of this current was carried out together with computation of the thermal (and anisotropic) conductivity and radiation. This calculation has shown that the stream leads to condensation when the dimensions of the arches are of the order of those observed in the corona. This calculation has also shown that the material of the prominence is renewed after one or two days, which also agrees with the observations.

The spicules constitute almost homogeneous columns of gas rising to a height of from seven to twelve thousand kilometers. The velocity at which they rise is 20–30 km/sec. Their formation is connected with the inhomogeneous structure of the magnetic field. The convective motions shift the lines of force, and as a result of such a diffusion the structure of the field becomes quite complex and fields of the opposite sign become close neighbors. These fields are compressed by the convective motions towards the periphery of the cells. At the neutral polarity-separation surfaces the field compresses the gas, which condenses and flows downward under the action of the force of gravity. As a result, compression continues and finally the intensity gradient attains a significant magnitude. It is connected with the current which heats the electronic component and generates ion sound. During this process the dissipation of magnetic energy increases and the lines of force filter through the layer of compressed gas and are annihilated; then the lines of force are reclosed (see the diagram). The magnetic loops which are formed raise the gas of the chromosphere up and thereby form a spicule. The equilibrium condition gives the necessary magnitude of the field, and the condition for generation of the ion sound gives the rate of reclosure of the field and hence the velocity of the rise. Both quantities agree well with observations.

An essential element of the structure of the chromosphere are the little filaments which are arranged along the lines of force and which connect two points with different polarity. Here it is necessary to explain why these filaments rise higher than the chromosphere and why they almost do not expand towards the center al-



though the lines of force must diverge. The normal chromosphere borders on the corona, where the temperature and the heat conductivity are high. On account of the flow of heat from the corona the upper part of the chromosphere vaporizes so that the boundary moves down lower than in a model without heat conductivity. When the magnetic arc passes low over the chromosphere, no corona is formed in it because the closed arc does not receive the heat flux. This results in a chromosphere-type of gas arc which is higher than the average level. The pressure of the gas falls with altitude, whereas in the surrounding corona it is practically constant. For this reason external pressure compresses the filament until the magnetic pressure counterbalances it. This explains the small thickness of the filament.

The content of this paper has been published in an article by the author in Astronomicheskiĭ zhurnal, No. 2 (1969) and are being published in Astronomicheskiĭ zhurnal, No. 2 (1971) and in the journal Solar Physics (1971). Moreover, older works by the author may be found in Astronomicheskiĭ zhurnal, No. 4 (1960) and No. 3 (1962).

V. L. Ginzburg, Pulsars—Present State of the Problem.

Introduction. A. Hewish has pointed out[1] that November 28, 1967 is the generally agreed upon date of the detection of pulsars. The first report of the discovery of pulsars was published in the February 24, 1968 number of Nature. Since then, already about 500 published articles have been devoted to experimental and theoretical investigation of pulsars. For about a year there has been observed a certain saturation on this question in the sense that no new results of a fundamental, qualitative character have appeared. In this connection the survey of this saturation made at one of the sessions of the Division of General Physics and Astronomy[2] in 1969 is still meaningful. The available experimental data have been compared in greater detail in[1]. For this reason we will cite below only briefly the contents of that part of the report which reflects the essential theoretical ideas regarding pulsars (for more details, see[3]).

1. The nature of pulsars. Attempts have been made to connect pulsars with neutron stars, white dwarfs, double stars, and objects of "a new type." When account is taken of the gravitational radiation, the hypothesis that pulsars are double stars becomes untenable. Now there is no basis for considering pulsars as objects of "a new type." If long-period and short-period pulsars are identical in nature, as is most probable, then pulsars cannot be rotating or pulsating white dwarfs as well as pulsating neutron stars. On the contrary, all pulsars can be identified with rotating neutron stars, with the period of the pulsar equal to the period of the rotation of the star or, in a certain particular case, to half of this period. Thus, it is quite probable, although it has not been rigorously proven, that pulsars are rotating neutron stars.

2. Rotating magnetized neutron stars. Upon transformation of a star into a neutron star, the moment of inertia is greatly reduced. For this reason it can be expected that neutron stars rotate rapidly (with an angular velocity $\Omega \lesssim 10^3$). It is equally probable that as a result of the compression of the well-conducting original star the magnetic field in the neutron star is very strong ($N \lesssim 10^{12}-10^{13}$ Oe). The magnetic moment m of the star, generally speaking, need not coincide with the direction of its angular velocity Ω. By the same token we obtain for pulsars, in a natural manner, a model of an inclined rotator (of a rotating magnetized neutron star with non-coinciding axes of rotation and of magnetic symmetry).

3. Structure of neutron stars and pulsars. In connection with an insufficiently exact knowledge of the equation of state of matter at ultrahigh densities ($\rho \gtrsim 10^{11}$ g-cm^{-3}), quantitative calculations for neutron stars are still unreliable. Nevertheless, it can be thought that for a "typical" neutron star the mass is $M \sim 0.5$, the radius is $r_0 \sim 10-30$ km and the density at the center is $\rho_c \sim 10^{15}$ g-cm^{-3}. At densities of $\rho \lesssim 3 \times 10^{11}$ g-cm^{-3} the material of the star consists of atomic nuclei and electrons, i.e., it is in a plasma state. If the thin surface layer of gas is not considered, the plasma part of the star is solid, that is, if forms a crust (here we are speaking about stars with a temperature of $T \lesssim (1-5) \times 10^8$ degrees; neutron stars can be hotter only immediately after they are formed). In the region of densities of $3 \times 10^{11} \lesssim \rho \lesssim 5 \times 10^{13}$ g-cm^{-3} the solid plasma crust contains also neutrons, the number of which grows with increasing density. Finally at densities of $\rho \lesssim 5 \times 10^{13}$ cm^{-3} the star consists basically of neutrons with an admixture of several percent of protons and an equal number of electrons (mesons and hyperons in a noticeable quantity appear only when $\rho \gtrsim 10^{15}$). The neutron-proton-electron region of neutron stars is liquid and consitutes, as it were, a mixture of neutron, proton, and electron liquids. There are strong reasons to suppose that in neutron stars the neutron liquid is in a superfluid state and that the proton liquid is in a superconducting state. Evidence in favor of the correctness of such a hypothesis, although it is still not proof of it, can be found in the analysis of the change of the period of the pulsar PSR 0833-45 in Velx Vela X after the abrupt change of its period observed in 1969. In one way or another a study of the discontinuities and other non-monotonic disturbances in the course of the secular increase of the period of the pulsars opens up prospects for "peeping" inside neutron stars.

4. The electrodynamics of rotating magnetized neutron stars. When it is in a vacuum the rotating magnetized neutron star that is an inclined rotator radiates low-frequency electromagnetic waves and also ejects charged particles from the surface of the star. As a result, the angular velocity of rotation of the star decreases. From this we can evaluate the magnetic field H_0 on the surface of the star, which turns out to be very