Preface to the Second Edition

The first edition, published in 2006, was addressed mainly to graduate students in astrophysics, space sciences and geophysics as well as to advanced students in applied physics and mathematics seeking a unified view of plasma physics and fluid mechanics. Lectures and seminars, given regularly since that time in the Faculty of Physics at the Moscow State University, have been found satisfactory by students, although new scientific tops, on which the students wanted to gain a view, have grown and multiplied. So, a considerable amount of new material, related to new space experiments that studied the Sun, interplanetary space, magnetosphere and distant astrophysical objects, should be added, at least briefly, to the lectures.

Solar physics gave wonderful examples of such news. Active regions at the Sun have been examined in extraordinary detail by space missions *Hinode*, *STEREO* and *Solar Dynamic Observatory* (*SDO*). Much attention to solar plasma is conditioned by the possibility of the all-round observational test of theoretical models. Moreover, new observations have provided the important data that needed to answer many new questions being not answered by previous observations. One of them, having not only scientific but also a practical relevance, is how to predict large solar flares. They strongly influence the near-Earth space by large-amplitude shock waves and flows of particles accelerated to high energies.

It is well known that solar active regions can accumulate a huge energy before a large flare in the form of interacting magnetic fluxes in the solar corona. That is why the topological features of magnetic fields play a fundamental role and have to be studied. The text of the first edition was much complemented in the sections on the possibility to investigate the topological properties of the large-scale magnetic fields in active regions in order to recognize a pre-flare situation at the Sun. In particular, such an analysis of the field topology shows that the so-called "topological trigger" effect should be taken into account when we model large eruptive flares and try to predict them.

Another trend in modern solar physics was initiated by the *RHESSI* observations of hard-X-ray sources in the solar corona. Such emission interpreted as the bremsstrahlung of fast electrons was not predicted by theory because of very low density of coronal plasma. However its appearance during solar flares clearly indicates generation of the so-called *super-hot* (with electron temperature $T_e \gtrsim 10\,\text{keV}$) plasma and an additional acceleration of electrons in the vicinity of reconnecting current layers, i.e. the main source of flare energy.

In the second edition, a reader will find a summary and illustrations of the most principal observational features of the coronal HXR sources. Then it is considered the model in which the fast electrons are accelerated in collapsing magnetic traps created by magnetic reconnection in super-hot turbulent-current layers in the corona. The comprehensive analytical consideration is taken for joint action of the Fermi-type first-order mechanism and betatron acceleration of fast electrons. Efficient trapping and continuous acceleration of the fastest electrons in the collapsing traps can also produce a large flux of microwaves in solar flares.

Thus, new space-borne observations of the Sun from *Hinode*, *RHESSI*, *SDO* and *STEREO* have produced stunning results, invigorated solar research and challenged existing theoretical models.

Significant progress in the theory of magnetic reconnection has been achieved in the last years. Based on the results of numerical and laboratory experiments on magnetic reconnection, new analytical models have been suggested. They have generalized the famous classical models by Petschek and Syrovatskii. The magnetic field in these models was assumed to be potential in the exterior of a current configuration that included Syrovatskii's thin current layer and four MHD discontinuous flows attached to the edges of the current layer. The flow pattern near the current layer was not prescribed but determined from a self-consistent solution of the MHD problem in the approximation of a strong magnetic field. These new models allow to study the global structure of magnetic field near the reconnection region and its local properties in the vicinity of the current layer and attached discontinuities.

Interesting results have been obtained in the classical theory of the small-amplitude MHD waves propagating in a compressible optically thin medium whose radiative cooling depends on the temperature in the form of one or more sharp maxima. In astrophysical plasmas, these maxima are produced by the radiation of a small admixture of heavy ions. In the solar corona, the damping of MHD oscillations due to the radiative energy losses is present and turns out to be strong for slow magnetoacoustic waves. Where the rate of energy losses at a maximum (i.e. at $T \sim 10^5\,\text{K}$), the brightness of the oscillating loops is at a maximum (i.e. in EUV) and, as a consequence, the MHD oscillations are damped more rapidly than in other places. That is why the rapidly damped oscillations are best seen in a small group of coronal loops observed in EUV radiation by satellites *TRACE* and *Hinode*.

New materials were added in almost every chapter of the second edition. For example, considering macroscopic description of astrophysical plasma, it was very useful to add the thirteen moment equations by Grad. They play a significant role in breaching the gap between hydrodynamics and kinetic theory in the problem of non-stationary powerful heat fluxes. In particular, it has appeared that the heat flux with consideration for the so-called "collisional relaxation" describes the heat transfer in solar flares much better than the classical Fourier law or anomalous heat fluxes.

References have been well updated but there will be no doubt that some important and relevant publications have been overlooked. This was not intentional. Plasma astrophysics is quickly developing in many astrophysical and related directions. So it is impossible to be aware of all the excellent papers published in these fields. I sincerely apologize for possible omissions in citations.

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