MHD Flows in Compact Astrophysical Objects

Accretion, Winds and Jets

Bearbeitet von
V.S. Beskin

1. Auflage 2012. Taschenbuch. xviii, 425 S. Paperback
ISBN 978 3 642 26177 0
Format (B x L): 15,5 x 23,5 cm
Gewicht: 682 g

Preface

This monograph is based on the lectures I gave to the staff of the Theoretical Astrophysics Department at the National Astronomical Observatory (Mitaka, Japan) in 1998. Later I incorporated them as part of a 1-year course in magnetohydrodynamics at the Department of Physics and Astrophysics Problems of the Moscow Institute of Physics and Technology and at the Astronomy Department of the Moscow State University. The monograph deals with one of the analytical approaches in modern astrophysics that goes back to the equation first formulated by H. Grad and V.D. Shafranov for static magnetic configurations. In a rather simple language, this approach can describe axisymmetric stationary flows that occur in a variety of astrophysical objects.

A lot of people were fascinated by the elegance of the Grad–Shafranov method and thought it could be used as the basic instrument for building realistic models of astrophysical systems. The Grad–Shafranov method has indeed become a tool for describing the fundamental physics of many such systems; however, it turned out that other methods are often needed for constructing more detailed models. The present course should be regarded in this context. Its aim is to invite further investigation rather than sum up the results.

A few words should be said about the prerequisites for this lecture course. These include familiarity with the main notions used in General Relativity (a covariant derivative, tensor algebra). However, as we will see, the use of the $3 + 1$-splitting formalism admits the formulation of all laws in the language of three-dimensional vectors with a clear physical meaning and substantially simplifies the representation of even the most complex flows in the neighborhood of rotating black holes. As an introduction to the $3 + 1$-splitting formalism, I strongly recommend the book "Black Holes. The Membrane Paradigm" edited by K. Thorne, D. MacDonald, and R. Price. This monograph can, in a sense, be regarded as the continuation of the first four chapters of this remarkable book (however, as I will show, the membrane approach does not always provide the correct interpretation of the processes in the vicinity of the black hole horizon).

I would like to precede the book with my personal reminiscences. I was the last undergraduate student of Sergey I. Syrovatskii. He was my scientific advisor at the Department of Physics and Astrophysics Problems for 3 years. He died of a second heart attack in the autumn of 1979, which was the year when I graduated from the

institute and started to study at the I.E. Tamm Theory Department of the P.N. Lebedev Physical Institute. So, I had no time to actually work with him. Nevertheless, bright memories of Sergey I. Syrovatskii are still in my heart. Moreover, after a number of years I realize that the influence my teacher had on me has become even stronger. Certainly, I think it is my duty to dedicate this book to the memory of Sergey I. Syrovatskii.

An article published in Physics Uspekhi says that the words "a life given to science" are not stereotypical when we speak about Sergey Syrovatskii. He belonged to the generation of the year 1925 and went to the front as many other 16-year-olds did (most of them gave their lives for the country). He was at the front throughout the war and was seriously wounded several times. Sergey I. Syrovatskii's heroic youth formed the major traits of his character that later helped him become one of the leading theoretical astrophysicists. Having suffered a most serious heart attack, he was torn away from his research for a few months but recovered his strength and continued to work as hard as before the illness. It is not accidental his portrait is next to the portraits of I.E. Tamm and A.D. Sakharov in the conference hall of the theory department.

Sergey I. Syrovatskii's scientific interests were broad and encompassed a variety of problems. He obtained the most important results in magnetohydrodynamics (classification of discontinuities and shock waves, the problem of their evolution, the stability analysis of tangential discontinuities), radio astronomy (the theory of synchrotron radiation that accounts for inhomogeneous distribution of electrons, their diffusion, and electron energy losses), cosmic ray astrophysics (the problems of the preferential acceleration of heavy nuclei and the universality of the spectrum), and solar physics. In 1964, he and V.L. Ginzburg wrote the fundamental monograph "The Origin of Cosmic Rays" that is still often cited, though great progress has been made in this area in the past 40 years.

I would like to stress the trait that, I think, truly characterizes Sergey Syrovatskii as a scientist. He liked exact solutions and spared no effort to study the two-dimensional flows in magnetohydrodynamics (complex variable methods can be used to efficiently obtain solutions in two dimensions, as opposed to three dimensions). His first significant work, which was on the evolutionarity of magnetohydrodynamic discontinuities, demonstrated the remarkable lucidity of his mind and the fundamentality of his scientific approach. Actually, all one needed was to accurately enumerate the number of equations and the unknowns (or, in the language of physics, the number of disturbances and waves that could transfer these disturbances) to obtain the result that was immediately included in the Landau–Lifshits course. When discussing scientific articles or student works in class, Sergey I. Syrovatskii would often stress the exactness (or, conversely, inexactness) of the formulation of physical problems and their boundary conditions. As we will see, it is the analysis of exact solutions that is the main theme of this book.

Sergey I. Syrovatskii believed that even the exact solutions of approximate equations are extremely important for forming our intuition that helps us qualitatively understand the basic properties of various physical processes. This shows, in particular, that he belonged to the I.E. Tamm school that maintained that any obser-

vational interpretation should be based on fundamental physics. Incidentally, as to this problem, he disagreed with Ya.B. Zeldovich who believed that, on the contrary, attention should principally be given to the analysis of approximate solutions of exact equations.

I stress that, in spite of a relatively small number of citations of Sergey I. Syrovatskii's journal articles, especially in recent years, he has been and remains a major authority in scientific circles. I think that, besides his high scientific potential, such traits of his character as the adherence to principles and kindness were crucial here. Besides, he had no envy of other scientists' advances in science. The issues of priority were of no interest to him at all. But he always stood up for the principles of scientific decency and respect for the work by others—principles he always strictly followed. Undoubtedly, the credit for forming the atmosphere of high scientific and moral standards, without which the truly golden age of Soviet astrophysics would be impossible, is given to S.I. Syrovatskii and S.B. Pikelner.

Apart from scientific research, Syrovatskii gave much of his time and effort to teaching. He established a scientific school united by the common aim—the development of a consistent theory of current sheets as applied to the flare processes on the Sun. S.V. Bulanov, V.A. Dogiel, A.G. Frank, B.V. Somov, and Yu. D. Zhugzhda are only a few of his disciples whose names speak for themselves. Certainly, his ability to unite and lead completely different people, see the positive potential in a heated argument, and settle the differences is just what was needed to establish a unique community of scientists able to challenge difficult scientific problems.

I remember how kind and polite he was with his students and disciples. Since I started to work at the department, I found myself in a peculiar atmosphere of creative work, its distinctive feature was friendly relations with the people around and complete equality before science. Needless to say that now working at the Department of Physics and Astrophysics Problems and giving the course of magnetohydrodynamics that was once read by S.I. Syrovatskii, I try to follow my teacher in many ways.

That is why, in recent years, when giving a lecture to a new audience, I often begin with the words: "I was Sergey Syrovatskii's last student . . ." And it is pleasant to see that the words inspire the audience, they act as a tuning fork helping me and the audience tune to the right state of mind.

Moscow, July 2009 *Vasily S. Beskin*

http://www.springer.com/978-3-642-01289-1

MHD Flows in Compact Astrophysical Objects
Accretion, Winds and Jets
Beskin, V.S.
2010, XVIII, 425 p., Hardcover
ISBN: 978-3-642-01289-1