

Magnetic Processes in Astrophysics: Theory, Simulations, Experiments by Gunther Rudiger, Rainer Hollerbach, Leonid L. Kitchatinov, Wiley, 2013, 356 pp., hardcover (E-book also available), 105.00/ 126.00, ISBN: 978-3-527-41034-7

It is by now a truism to note that magnetic fields are ubiquitous in astrophysics: from the formation of stars to their eventual death, from the grandest galaxy to the rockiest planet, few astrophysical processes or objects are completely untouched by magnetism. Like gravity, its influence can extend over the great distances that characterize such objects, but can also be seen on the scales of everyday life: the magnet on your kitchen refrigerator, the needle in your compass. Yet the physics that underlies the generation of magnetic fields in astrophysical and geophysical bodies seems remarkably generic, with the motion of electrically conducting fluids coupled to rotation playing a critical role; likewise the host of instabilities that can cause a pre-imposed magnetic field to decay or evolve find expression in both the lab and in the cosmos.

With a whole universe of possible applications on which to focus, it should come as no surprise that a book with the ambitious and sweeping title of "Magnetic Processes in Astrophysics: theory, simulations, experiments" has had to pick its battles. Perhaps a more descriptive (though less publishable) title would have been "Magnetofluid instabilities and differential rotation," since these are the topics that occupy the bulk of the text. The choice of subject matter here largely reflects the authors' main areas of expertise: Rudiger was for many years the head of the prolific Potsdam MHD group, and has been one of the most able practitioners of mean-field (magneto)hydrodynamics for decades. Kitchatinov has, with him, written many significant papers on mean-field models of transport (of heat, angular momentum, and magnetism) by turbulent convection, among other contributions to the field. Hollerbach adds considerable expertise in geomagnetism, and in flows and instabilities in laboratory settings. Rudiger and Hollerbach wrote the respected 2004 book "The magnetic universe: geophysical and astrophysical dynamo theory". In comparison to that book, the present volume focuses more on the wider class of MHD instabilities – i.e., not just on dynamos – and has more discussion of experiments; it also, of course, provides a number of significant updates from the work on this subject over the past decade.

Two of the chapters (Chapter 1 and Chapter 4) focus primarily on specific

astrophysical problems; the others deal in a somewhat more general way with the instabilities that arise in a host of objects, cosmic or otherwise. Chapter 1 deals with differential rotation in stars, and provides a thorough summary of both the observational literature on the subject and the authors' decades-long attempts to understand the origins of these zonal flows. Though there is considerable overlap with the treatment of the same subject in the 2004 book (indeed, some sentences appear almost verbatim in both), there are a few significant changes and updates. A real strength of this chapter is the frequent comparison to numerical simulations on this topics that have appeared in the decade or so since "The Magnetic Universe" appeared; there are several comparisons between these and the authors' analytical theory, drawn mostly from the published literature but surveyed well here. The illustrations are well-chosen and drawn from a variety of sources. Chapter 4 briefly summarizes (in under 30 pages) observations, mean-field models, and simulations of MHD processes in galaxies. Here again there is some overlap with the 2004 book (which featured a chapter on "the galactic dynamo"), but here the focus is somewhat broader in scope (including, for example, the possibility of Tayler instability in galaxies) and the text again benefits from reference to some of the many interesting simulations in this area that have appeared since 2004.

Chapter 3 seems more pedagogical in intent: it describes the "quasi-linear theory of driven turbulence" in general, and then applies the theory to several problems of current interest in convection and dynamo theory. Among other things, there is an interesting analysis of what has been termed the "negative effective magnetic pressure instability", related to the idea that magnetic fields might so suppress an initial turbulent flow that they could lead to a negative total pressure perturbation. Here the authors show analytically that (within the context of a particular mixing-length model, at particular parameters, using quasi-linear theory) that there are cases in which no negative-pressure phenomena can be realized at any field strength.

The remaining chapters deal primarily with MHD instabilities in a more general fashion, with some topics appearing in a few different places with different contexts. Chapter 2 is described as "radiation zones: magnetic stability and rotation", and in large part is a collection of the authors' (and their collaborators') published work on this subject. (About two-thirds of the figures in this chapter are from papers featuring one or more of these authors.) They discuss the stability of fields in a variety of circumstances, and analyze the prospects for dynamos in such stably stratified regions. Chapter 5 is

titled "the magnetorotational instability (MRI)", but also includes (indeed, begins) with a substantial discussion of Taylor-Couette flow and instabilities in stratified (but unmagnetized) flows before actually getting to the MRI. There is considerable emphasis given to linear stability calculations, with many plots outlining regions of (in)stability in various cases. There is also a short but interesting summary of efforts to realize the MRI in a laboratory setting. Chapter 6 is devoted to the Taylor instability, and analyzes both the instability itself and some of its effects. The chapter has a thorough summary of the stabilization of the instability by rotation (including both rigid and differential cases), and a substantial analysis of the angular momentum transport, mixing, and field generation by means of the instability. An experimental setup designed to study these instabilities is described, and some early results from it presented. Again, most of the work here (and about two-thirds of the figure set) is excerpted from papers by the authors. Chapter 7 contains a virtually stand-alone analysis of magnetic spherical Couette flow, and flows smoothly from one aspect of this problem to another. The basic problem setup, the linear instability theory, and a selection of experimental results are thoroughly described and well illustrated. There are also some interesting digressions on magnetostrophic MRI, dynamo action, and a few other topics.

Each of these topics is considered thoroughly and seriously here; there are a variety of insights, factoids, and interesting comparisons between theory and simulation or experiment scattered throughout. The topics it covers, it generally covers well.

Nonetheless, the book has its weaknesses, or at least its peculiarities. At times it feels more like a collection of the authors' disparate papers than an attempt to survey the vast field alluded to in the book's title; certainly it is more of a summary of selected topics, some of them fairly technical, than a synthesis. With some exceptions (e.g., Chapter 7) the book isn't particularly pedagogical in nature – many topics are introduced without much background or astrophysical/geophysical motivation, so a student might find it heavy going. The selection of topics, and the way and order in which these are presented, is occasionally a little idiosyncratic. For example, there is a whole chapter on the magnetorotational instability; but if you were previously unaware that the MRI is now thought by many astrophysicists to play a significant role in the transport of angular momentum in accretion disks of all kinds – allowing in turn for the growth of objects ranging from stars to supermassive black holes – you probably wouldn't learn it from this chapter.

Accretion disks are barely mentioned, and many seminal papers establishing the likely relevance of the instability to astrophysical disks ignored. In comparison to the 2004 "Magnetic Universe" book by Rudiger and Hollerbach, this volume spends less time on basic explanations or physical principles; it reads less as a coherent book, meant to be read in a given order, than as a collection of related articles on MHD instabilities. Given this, it seems to be meant less as a textbook than as a reference to the current state of these topics, often as viewed through the lens of quasi-linear theory.

I would nonetheless recommend the book for workers (or perhaps post-graduate students) in this area who desire an up-to-date summary of the field of MHD instabilities in stellar (and to some extent laboratory) settings. There is no better summary of the authors' own considerable contributions to this area – and even if it would have been nice to hear the authors' thoughts on a wider range of topics, one cannot fault them for sticking mostly to the areas where they have had the greatest impact. The frequent comparisons between theory and experiment or simulation are a nice asset, and are drawn in many cases from the most recent possible papers. Finally, though there is some substantial overlap with the material in "Magnetic Universe", there is also much that is new, and readers who own the 2004 book might well wish this one as an up-to-date companion volume.

Matthew Browning
University of Exeter