Astrophysical Radiation Hydrodynamics

#astrophysics #radiation hydrodynamics #fluid dynamics #stellar evolution #cosmic phenomena

Astrophysical Radiation Hydrodynamics is a crucial field that examines the intricate interplay between radiation and fluid motion within various cosmic environments. This discipline is fundamental for understanding complex phenomena such as star formation, supernovae explosions, accretion disk dynamics around black holes, and the early universe, where intense radiation fields significantly influence the behavior and evolution of gas and plasma.

Each syllabus includes objectives, reading lists, and course assessments.

Astrophysical Radiation Hydrodynamics

This NATO Advanced Research Workshop was devoted to the pre sentation, evaluation, and critical dis- cussion of numerical methods in nonrelativistic and relativistic hydrodynamics, radia tive transfer, and radiation-coupled hydrodynamics. The unifying theme of the lectures was the successful application of these methods to challenging problems in astrophysics. The workshop was subdivided into 3 somewhat independent topics, each with their own subtheme. Under the heading radiation hydrodynamics were brought together context, theory, methodology, and application of radia tive transfer and radiation hydrodynamics in astrophysics. The intimate coupling between astronomy and radiation physics was underscored by examples from past and present research. Frame-dependence of both the equation of transfer (plus moments) and the underlying radiation quantities was discussed and clarified. Limiting regimes in radiation-coupled flow were identified and described; the dynamic diffusion regime received special emphasis. Numerical methods for continuum and line transfer equations in a given background were presented. Two examples of methods for computing dynamically coupled radia tion/matter fields were given. In l-d and assuming LTE the complete equations of radiation hydrodynamics can be solved with current computers. Such is not the case in 2- or 3-d, which were identified as target areas for research. The use of flux-limiters was vigorously discussed in this connection, and enlivened the meeting.

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Fundamentals of Astrophysical Fluid Dynamics

This book offers an overview of the fundamental dynamical processes, which are necessary to understand astrophysical phenomena, from the viewpoint of hydrodynamics, magnetohydrodynamics, and radiation hydrodynamics. The book consists of three parts: The first discusses the fundamentals of hydrodynamics necessary to understand the dynamics of astrophysical objects such as stars, interstellar gases and accretion disks. The second part reviews the interactions between gases and magnetic fields on fluid motions – the magnetohydrodynamics – highlighting the important role of magnetic fields in dynamical phenomena under astrophysical environments. The third part focuses on radiation hydrodynamics, introducing the hydrodynamic phenomena characterized by the coupling of radiation and gas motions and further on relativistic radiation hydrodynamics. Intended as a pedagogical introduction for advanced undergraduate and graduate students, it also provides comprehensive coverage of the fundamentals of astrophysical fluid dynamics, making it an effective resource not only for graduate courses, but also for beginners wanting to learn about hydrodynamics, magnetohydrodynamics, and radiation hydrodynamics in astrophysics independently.

Foundations of Radiation Hydrodynamics

Excellent, informative volume focuses on dynamics of nonradiating fluids, problems involving waves, shocks and stellar winds, physics of radiation, radiation transport, and the dynamics of radiating fluids. 1984 edition.

Radiation Hydrodynamics

The discipline of radiation hydrodynamics is the branch of hydrodynamics in which the moving fluid absorbs and emits electromagnetic radiation, and in so doing modifies its dynamical behavior. That is, the net gain or loss of energy by parcels of the fluid material through absorption or emission of radiation are sufficient to change the pressure of the material, and therefore change its motion; alternatively, the net momentum exchange between radiation and matter may alter the motion of the matter directly. Ignoring the radiation contributions to energy and momentum will give a wrong prediction of the hydrodynamic motion when the correct description is radiation hydrodynamics. Of course, there are circumstances when a large quantity of radiation is present, yet can be ignored without causing the model to be in error. This happens when radiation from an exterior source streams through the problem, but the latter is so transparent that the energy and momentum coupling is negligible. Everything we say about radiation hydrodynamics applies equally well to neutrinos and photons (apart from the Einstein relations, specific to bosons), but in almost every area of astrophysics neutrino hydrodynamics is ignored, simply because the systems are exceedingly transparent to neutrinos, even though the energy flux in neutrinos may be substantial. Another place where we can do "radiation hydrodynamics" without using any sophisticated theory is deep within stars or other bodies, where the material is so opaque to the radiation that the mean free path of photons is entirely negligible compared with the size of the system, the distance over which any fluid quantity varies, and so on. In this case we can suppose that the radiation is in equilibrium with the matter locally, and its energy, pressure and momentum can be lumped in with those of the rest of the fluid. That is, it is no more necessary to distinguish photons from atoms, nuclei and electrons, than it is to distinguish hydrogen atoms from helium atoms, for instance. There are all just components of a mixed fluid in this case. So why do we have a special subject called "radiation hydrodynamics", when photons are just one of the many kinds of particles that comprise our fluid? The reason is that photons couple rather weakly to the atoms, ions and electrons, much more weakly than those particles couple with each other. Nor is the matter-radiation coupling negligible

in many problems, since the star or nebula may be millions of mean free paths in extent. Radiation hydrodynamics exists as a discipline to treat those problems for which the energy and momentum coupling terms between matter and radiation are important, and for which, since the photon mean free path is neither extremely large nor extremely small compared with the size of the system, the radiation field is not very easy to calculate. In the theoretical development of this subject, many of the relations are presented in a form that is described as approximate, and perhaps accurate only to order of {nu}/c. This makes the discussion cumbersome. Why are we required to do this? It is because we are using Newtonian mechanics to treat our fluid, yet its photon component is intrinsically relativistic; the particles travel at the speed of light. There is a perfectly consistent relativistic kinetic theory, and a corresponding relativistic theory of fluid mechanics, which is perfectly suited to describing the photon gas. But it is cumbersome to use this for the fluid in general, and we prefer to avoid it for cases in which the flow velocity satisfies {nu} “c. The price we pay is to spend extra effort making sure that the source-sink terms relating to our relativistic gas component are included in the equations of motion in a form that preserves overall conservation of energy and momentum, something that would be automatic if the relativistic equations were used throughout.

Radiation Hydrodynamics

Publisher Description

Recent Directions in Astrophysical Quantitative Spectroscopy and Radiation Hydrodynamics

The meeting was organized to honor Dimitri Mihalas for his lifetime contributions to the fields of astrophysical quantitative spectroscopy and radiation hydrodynamics on the occasion of his 70th birthday. The meeting covered recent developments and future prospects in general radiative transfer theory, modeling stellar atmospheres, theory and modeling of stellar winds, and basic theory and applications of the astrophysical radiation hydrodynamics.

Computational Methods for Astrophysical Fluid Flow

This book leads directly to the most modern numerical techniques for compressible fluid flow, with special consideration given to astrophysical applications. Emphasis is put on high-resolution shock-capturing finite-volume schemes based on Riemann solvers. The applications of such schemes, in particular the PPM method, are given and include large-scale simulations of supernova explosions by core collapse and thermonuclear burning and astrophysical jets. Parts two and three treat radiation hydrodynamics. The power of adaptive (moving) grids is demonstrated with a number of stellar-physical simulations showing very crispy shock-front structures.

Relativistic Astrophysics of the Transient Universe

This unified treatment of electromagnetic, hadronic and gravitational radiation processes associated with relativistic outflows from compact objects is ideal for researchers interested in the transient universe. It examines relativistic outflows and radiation processes and links contemporary astronomy to gravitational-wave experiments.

The Equations of Radiation Hydrodynamics

Graduate-level text examines propagation of thermal radiation through a fluid and its effects on the hydrodynamics of fluid motion. Topics include approximate formulations of radiative transfer and relativistic effects of fluid motion; microscopic physics associated with the equation of transfer; inverse Compton scattering; and hydrodynamic description of fluid. 1973 edition.

Astrophysical Formulae

This classic reference for the fundamental formulae of physics and astrophysics has become part of nearly every astronomers and astrophysicists library. "A magnificent compendium" - OPTICA ACTA (ON THE FIRST EDITION)

Numerical Methods in Astrophysics

Numerical Methods in Astrophysics: An Introduction outlines various fundamental numerical methods that can solve gravitational dynamics, hydrodynamics, and radiation transport equations. This resource

indicates which methods are most suitable for particular problems, demonstrates what the accuracy requirements are in numerical simulations, a

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Foundations of High-Energy Astrophysics

Written by one of today’s most highly respected astrophysicists, Foundations of High-Energy Astrophysics is an introduction to the mathematical and physical techniques used in the study of high-energy astrophysics. Here, Mario Vietri approaches the basics of high-energy astrophysics with an emphasis on underlying physical processes as opposed to a more mathematical approach. Alongside more traditional topics, Vietri presents new subjects increasingly considered crucial to understanding high-energy astrophysical sources, including the electrodynamics of cosmic sources, new developments in the theory of standard accretion disks, and the physics of coronae, thick disks, and accretion onto magnetized objects. The most thorough and engaging survey of high-energy astrophysics available today, Foundations of High-Energy Astrophysics introduces the main physical processes relevant to the field in a rigorous yet accessible way, while paying careful attention to observational issues. Vietri’s book will quickly become a classic text for students and active researchers in astronomy and astrophysics. Those in adjoining fields will also find it a valuable addition to their personal libraries.

Astrophysical Hydrodynamics

This latest edition of the proven and comprehensive treatment on the topic -- from the bestselling author of "Tapestry of Modern Astrophysics" -- has been updated and revised to reflect the newest research results. Suitable for AS0000 and AS0200 courses, as well as advanced astrophysics and astronomy lectures, this is an indispensable theoretical backup for studies on celestial body formation and astrophysics. Includes exercises with solutions.

An Introduction to Astrophysical Hydrodynamics

This book is an introduction to astrophysical hydrodynamics for both astronomy and physics students. It provides a comprehensive and unified view of the general problems associated with fluids in a cosmic context, with a discussion of fluid dynamics and plasma physics. It is the only book on hydrodynamics that addresses the astrophysical context. Researchers and students will find this work to be an exceptional reference. Contents include chapters on irrotational and rotational flows, turbulence, magnetohydrodynamics, and instabilities.

Radiation Hydrodynamics in Stars and Compact Objects

Beginning from first principles and adopting a modular structure, this book develops the fundamental physical methods needed to describe and understand a wide range of seemingly very diverse astrophysical phenomena and processes. For example, the discussion of radiation processes including their spectra is based on Larmor's equation and extended by the photon picture and the internal dynamics of radiating quantum systems, leading to the shapes of spectral lines and the ideas of radiation transport. Hydrodynamics begins with the concept of phase-space distribution functions and Boltzmann's equation and develops ideal, viscous and magneto-hydrodynamics all from the vanishing divergence of an energy-momentum tensor, opening a natural extension towards relativistic hydrodynamics. Linear stability analysis is introduced and used as a common and versatile tool throughout the book. Aimed at students at graduate level, lecturers teaching courses in theoretical astrophysics or advanced topics in modern astronomy, this book with its abundant examples and exercises also serves as a reference and an entry point for more advanced researchers wanting to update their knowledge of the physical processes that govern the behavior and evolution of astronomical objects.

Astrophysical Formulae

This book by a Nobel Laureate provides the foundation for analysis of stellar atmospheres, planetary illumination, and sky radiation. Suitable for students and professionals in physics, nuclear physics, astrophysics, and atmospheric studies. 1950 edition.

Theoretical Astrophysics

This first course in fluid dynamics covers the basics and introduces a wealth of astronomical applications.

Radiative Transfer

This book provides an up-to-date, lively and approachable introduction to the mathematical formalism, numerical techniques and applications of relativistic hydrodynamics. The topic is presented here in a form which will be appreciated both by students and researchers in the field.

Astrophysical Fluid Dynamics

This book addresses key topics in stellar structure and evolution, including the structure and evolution of single and binary stars of various masses, the theory of stellar oscillations based on radiation hydrodynamics, and the theory of stellar atmosphere. Numerical modeling sets are included for all the topics presented in the book.

Relativistic Hydrodynamics

Bright gamma-ray flares observed from sources far beyond our Milky Way Galaxy are best explained if enormous amounts of energy are liberated by black holes. The highest- energy particles in nature--the ultra-high-energy cosmic rays--cannot be confined by the Milky Way's magnetic field, and must originate from sources outside our Galaxy. Understanding these energetic radiations requires an extensive theoretical framework involving the radiation physics and strong-field gravity of black holes. In High Energy Radiation from Black Holes, Charles Dermer and Govind Menon present a systematic exposition of black-hole astrophysics and general relativity in order to understand how gamma rays, cosmic rays, and neutrinos are produced by black holes. Beginning with Einstein's special and general theories of relativity, the authors give a detailed mathematical description of fundamental astrophysical radiation processes, including Compton scattering of electrons and photons, synchrotron radiation of particles in magnetic fields, photohadronic interactions of cosmic rays with photons, gamma-ray attenuation, Fermi acceleration, and the Blandford-Znajek mechanism for energy extraction from rotating black holes. The book provides a basis for graduate students and researchers in the field to interpret the latest results from high-energy observatories, and helps resolve whether energy released by rotating black holes powers the highest-energy radiations in nature. The wide range of detail will make High Energy Radiation from Black Holes a standard reference for black-hole research.

Theoretical and Computational Radiation Hydrodynamics

In order to bring the scientific events of the meetings of the Astronomische Gesellschaft (AG) to the attention of the worldwide astronomical community, an annual publication, Reviews in Modern Astronomy, was established. It is devoted exclusively to . the invited reviews, the Karl Schwarz schild lectures, and the high light contributions from leading scientists reporting on recent progress and scientific achievements at their respective institutes. This third volume continues the yearbook series of publications of the society. It comprises the complete set of contributions presented during the spring meeting of the AG at Berlin in March 1990, which was dedicated to the topic "Accretion and Winds". In addition four latecomers (two review and two highlight papers) delivered at the fall meeting at Graz, Austria in September 1989 close this volume. Heidelberg, September 1990 G: Klare Contents Some New Elements in Accretion Disk Theory By F. Meyer (With 5 Figures) . . . . . 1 Mass Transfer and Evolution in Close Binaries By A. R. King (With 4 Figures) . . . . . 14 Radiation Hydrodynamics of the Boundary Layer of Accretion Disks in Cataclysmic Variables By W. Kley (With 6 Figures) . . . . . 21 Curious Observations of Cataclysmic Variables By F. V. Hessman (With 10 Figures) . . . . . 32 Accretion in AM Herculis Stars 44 By A. D. Schwope (With 12 Figures) X-ray Diagnostics of Accretion Disks By G. Hasinger (With 12 Figures) . .

. . . . . 60 Accretion Phenomena at Neutron Stars By A. Rebetzky, H. Herold, U. Kraus, H. -P. Nollert, and H. Ruder (With 13 Figures) . . . . . .

Relativistic Hydrodynamics and Magnetohydrodynamics

This two-volume text is for new graduates on astronomy courses who need to get to grips with the physics involved in the subject. Four problem sets, averaging three problems per set, accompany each volume. The problems expand on the material covered in the texts and represent the level of calculational skill needed to write scientific papers in contemporary astrophysics.

Stellar Astrophysics

The raw numbers of high-energy-density physics are amazing: shock waves at hundreds of km/s (approaching a million km per hour), temperatures of millions of degrees, and pressures that exceed 100 million atmospheres. This title surveys the production of high-energy-density conditions, the fundamental plasma and hydrodynamic models that can describe them and the problem of scaling from the laboratory to the cosmos. Connections to astrophysics are discussed throughout. The book is intended to support coursework in high-energy-density physics, to meet the needs of new researchers in this field, and also to serve as a useful reference on the fundamentals. Specifically the book has been designed to enable academics in physics, astrophysics, applied physics and engineering departments to provide in a single-course, an introduction to fluid mechanics and radiative transfer, with dramatic applications in the field of high-energy-density systems. This second edition includes pedagogic improvements to the presentation throughout and additional material on equations of state, heat waves, and ionization fronts, as well as problem sets accompanied by solutions.

High Energy Radiation from Black Holes

A good working knowledge of fluid mechanics and plasma physics is essential for the modern astrophysicist. This graduate textbook provides a clear, pedagogical introduction to these core subjects. Assuming an undergraduate background in physics, this book develops fluid mechanics and plasma physics from first principles. This book is unique because it presents neutral fluids and plasmas in a unified scheme, clearly indicating both their similarities and their differences. Also, both the macroscopic (continuum) and microscopic (particle) theories are developed, establishing the connections between them. Throughout, key examples from astrophysics are used, though no previous knowledge of astronomy is assumed. Exercises are included at the end of chapters to test the reader's understanding. This textbook is aimed primarily at astrophysics graduate students. It will also be of interest to advanced students in physics and applied mathematics seeking a unified view of fluid mechanics and plasma physics, encompassing both the microscopic and macroscopic theories.

Accretion and Winds

The most authoritative synthesis of the quantitative spectroscopic analysis of stellar atmospheres This book provides an in-depth and self-contained treatment of the latest advances achieved in quantitative spectroscopic analyses of the observable outer layers of stars and similar objects. Written by two leading researchers in the field, it presents a comprehensive account of both the physical foundations and numerical methods of such analyses. The book is ideal for astronomers who want to acquire deeper insight into the physical foundations of the theory of stellar atmospheres, or who want to learn about modern computational techniques for treating radiative transfer in non-equilibrium situations. It can also serve as a rigorous yet accessible introduction to the discipline for graduate students. Provides a comprehensive, up-to-date account of the field Covers computational methods as well as the underlying physics Serves as an ideal reference book for researchers and a rigorous yet accessible textbook for graduate students An online illustration package is available to professors at press.princeton.edu

The Physics of Astrophysics: Gas dynamics

Introduces hydrodynamics to undergraduate students in physics and astrophysics. Stellar winds are a common phenomenon in the life of stars, from the dwarfs like the Sun to the red giants and hot supergiants, constituting one of the basic aspects of modern astrophysics. Stellar winds are a hydrodynamic phenomenon in which circumstellar gases expand towards the interstellar medium. This book presents an elementary introduction to the fundamentals of hydrodynamics with an application to the study of stellar winds. The principles of hydrodynamics have many other applications, so that the

book can be used as an introduction to hydrodynamics for students of physics, astrophysics and other related areas.

High-Energy-Density Physics

Many large-scale projects for detecting gravitational radiation are currently being developed, all with the aim of opening a new window onto the observable Universe. As a result, numerical relativity has recently become a major field of research, and Elements of Numerical Relativity and Relativistic Hydrodynamics is a valuable primer for both graduate students and non-specialist researchers wishing to enter the field. A revised and significantly enlarged edition of LNP 673 Elements of Numerical Relativity, this book starts with the most basic insights and aspects of numerical relativity before it develops coherent guidelines for the reliable and convenient selection of each of the following key aspects: evolution formalism; gauge, initial, and boundary conditions; and various numerical algorithms. And in addition to many revisions, it includes new, convenient damping terms for numerical implementations, a presentation of the recently-developed harmonic formalism, and an extensive, new chapter on matter space-times, containing a thorough introduction to relativistic hydrodynamics. While proper reference is given to advanced applications requiring large computational resources, most tests and applications in this book can be performed on a standard PC.

The Physics of Fluids and Plasmas

Emphasising computational modeling, this introduction to the physics on matter at extreme conditions is invaluable for researchers and graduate students.

Theory of Stellar Atmospheres

This 2001 book presents the methodologies used by astrophysicists for solving the radiative transfer equation.

Hydrodynamics and Stellar Winds

These are the proceedings of international conference on Numerical As trophysics 1998 (NAP98), held at National Olympic Memorial Youth Cen ter, in Tokyo, Japan in the period of March 10 - 13, 1998, and hosted by the National Astronomical Observatory, Japan (NAOJ). In the last decade numerical simulations have grown up as a major tool for astrophysics. Numerical simulations give us invaluable in- forma tion on complex systems and physical processes under extreme conditions which can be neither realized by experiments nor directly observed. Super computers and special purpose computers may work as very large telescopes and special purpose telescopes for theoretical astrophysics, respectively. Nu merical astrophysics ranks with other tool-oriented astronomy such as ra dio astronomy, infrared astronomy, ultraviolet astronomy, X-ray astronomy, and ')'-ray astronomy. This conference, NAP98, was planned to explore recent advances in astrophysics aided by numerical simulations. The subjects of the confer ence included the large-scale structure formation, galaxy formation and evolution, star and planets formation, accretion disks, jets, gravitational wave emission, and plasma physics. NAP98 had also sessions on numerical methods and computer science. The conference was attended by 184 sci entists from 21 countries. We enjoyed excellent talks, posters, videos, and discussions: there are 40 oral presentations, 96 posters and 16 video pre sentations. We hope that these proceedings and accompanying CD-ROM replay the friendly but inspiring atmosphere of the conference.

Elements of Numerical Relativity and Relativistic Hydrodynamics

Astrophysics: Decoding the Cosmos is an accessible introduction to the key principles and theories underlying astrophysics. This text takes a close look at the radiation and particles that we receive from astronomical objects, providing a thorough understanding of what this tells us, drawing the information together using examples to illustrate the process of astrophysics. Chapters dedicated to objects showing complex processes are written in an accessible manner and pull relevant background information together to put the subject firmly into context. The intention of the author is that the book will be a ‘tool chest’ for undergraduate astronomers wanting to know the how of astrophysics. Students will gain a thorough grasp of the key principles, ensuring that this often-difficult subject becomes more accessible.

Extreme Physics

Bridging the gap between physics and astronomy textbooks, this book provides step-by-step physical and mathematical development of fundamental astrophysical processes underlying a wide range of phenomena in stellar, galactic, and extragalactic astronomy. The book has been written for upper-level undergraduates and beginning graduate students, and its strong pedagogy ensures solid mastery of each process and application. It contains over 150 tutorial figures, numerous examples of astronomical measurements, and 201 exercises. Topics covered include the Kepler–Newton problem, stellar structure, binary evolution, radiation processes, special relativity in astronomy, radio propagation in the interstellar medium, and gravitational lensing. Applications presented include Jeans length, Eddington luminosity, the cooling of the cosmic microwave background (CMB), the Sunyaev–Zeldovich effect, Doppler boosting in jets, and determinations of the Hubble constant. This text is a stepping stone to more specialized books and primary literature. Password-protected solutions to the exercises are available to instructors at www.cambridge.org/9780521846561.

An Introduction to Radiative Transfer

A valuable and complete resource that brings together many of the branches of physics needed in high-energy-density physics. Targeted at research scientists and graduate students in physics and astrophysics, this book begins with basic concepts and develops a detailed explanation of the physics of hydrodynamics and energy transport in plasma.

Numerical Astrophysics

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Astrophysics

Astrophysics Processes