

DIFFUSION APPROXIMATION IN A RADIATIVE TRANSFER MODEL FOR ASTROPHYSICAL FLOWS

LAURENT DI MENZA¹, CLAIRE MICHAUT² AND OCÉANE SAINCIR³

Abstract. In this work, we present the diffusion approximation model for radiative transfer when we deal with optically thick astrophysical flows. Since the initial model is high CPU time demanding when dealing with its numerical approximation, solving this simpler system can provide a low cost strategy for the simulation of radiative media. We then use a finite-volume algorithm coupled with an implicit scheme for radiative contributions to solve this simplified system. Numerical experiments in the one-dimensional and two dimensional cases are presented to validate our numerical strategy and to prove the relevance of this asymptotic model.

Résumé. Nous présentons dans ce travail un modèle du régime de la diffusion pour le transfert radiatif dans le cas où le milieu est optiquement très épais pour la description d'écoulements astrophysiques. Ce modèle permet d'envisager des stratégies numériques moins coûteuses en temps que le modèle M1 pour la simulation de processus radiatifs. Nous utilisons pour cela une méthode de type volumes finis couplée à un schéma implicite pour les termes de rayonnement et nous présentons des résultats de simulations numériques en dimension 1 et 2 d'espace permettant de valider notre algorithme et de montrer la pertinence de ce modèle.

1. INTRODUCTION

The comprehension of realistic astrophysical phenomena has been the subject of many challenging studies for decades, with various applications in stellar physics such as the study of jets in the formation of young stars involving matter accretion, stellar winds and dynamics of supernova remnants. Within this framework, a wide complexity occurs for different reasons. First, these phenomena involve both hydrodynamics and radiative processes (see [16], [18], [23]). The latter ones are driven by the propagation of photons at the speed of light, which means that typical velocities completely differ between hydrodynamic and radiation scales. This causes a strong coupling between fluid and radiation since the behavior of the medium at a given point may depend on quantities which need to be evaluated on a large spatial zone (the physical effects are said to be *nonlocal*). Moreover, in the general case the analytical expression for the physical values under study is out of reach due to the complexity of the governing model. In this case, one can use numerical methods in order to simulate the physical phenomena as accurately as possible. Consequently, mathematical algorithms that are involved have to be consistent with the desired solutions (see [21]). In particular, they have to tolerate discontinuities that may spatially propagate (known as "shock waves") and they have to produce physically relevant results (namely

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Astrophysical Flows Andrew King

**Maurizio Falanga, Tomaso
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Supermassive Black Holes Andrew King, 2023-03-30 An accessible introduction to the new and cutting edge concepts in supermassive black hole research for graduate students and researchers *Accretion Power in Astrophysics* Juhan Frank, A. R. King, Derek Raine, 2002-01-17 *Accretion Power in Astrophysics* examines accretion as a source of energy in both binary star systems containing compact objects and in active galactic nuclei Assuming a basic knowledge of physics the authors describe the physical processes at work in accretion discs and other accretion flows The first three chapters explain why accretion is a source of energy and then present the gas dynamics and plasma concepts necessary for astrophysical applications The next three chapters then develop accretion in stellar systems including accretion onto compact objects Further chapters give extensive treatment of accretion in active galactic nuclei and describe thick accretion discs A new chapter discusses recently discovered accretion flow solutions The third edition is greatly expanded and thoroughly updated New material includes a detailed treatment of disc instabilities irradiated discs disc warping and general accretion flows The treatment is suitable for advanced undergraduates graduate students and researchers **Astrophysical Flows** James Edward Pringle, 2007 This graduate textbook provides a basic understanding of the fluid dynamical processes relevant to astrophysics Topics covered include wave propagation shocks spherical flows stellar oscillations the instabilities caused by effects such as magnetic fields thermal driving gravity shear flows and more **The Physics of Accretion onto Black Holes** Maurizio Falanga, Tomaso Belloni, Piergiorgio Casella, Marat Gilfanov, Peter Jonker, Andrew King, 2014-10-28 Provides a comprehensive summary on the physical models and current theory of black hole accretion growth and mergers in both the supermassive and stellar mass cases This title reviews in depth research on accretion on all scales from galactic binaries to intermediate mass and supermassive black holes Possible future directions of accretion are also discussed The following main themes are covered a historical perspective physical models of accretion onto black holes of all masses black hole fundamental parameters and accretion jets and outflows An overview and outlook on the topic is also presented This volume

summarizes the status of the study of astrophysical black hole research and is aimed at astrophysicists and graduate students working in this field Originally published in Space Science Reviews Vol 183 1 4 2014 **The Observatory** ,1997 Black Hole Formation and Growth Tiziana Di Matteo,Andrew King,Neil J. Cornish,2019-10-31 The ultimate proofs that black holes exist have been obtained very recently thanks to the detection of gravitational waves from their coalescence and due to material orbiting at a distance of some gravitational radii imaged by optical interferometry or X ray reverberation mapping This book provides three comprehensive and up to date reviews covering the gravitational wave breakthrough our understanding of accretion and feedback in supermassive black holes and the relevance of black holes for the Universe since the Big Bang Neil J Cornish presents gravitational wave emission from black hole mergers and the physics of detection Andrew King reviews the physics of accretion on to supermassive black holes and their feedback on host galaxies Tiziana Di Matteo addresses our understanding of black hole formation at cosmic dawn the emergence of the first quasars black hole merging and structure formation The topics covered by the 48th Saas Fee Course provide a broad overview of the importance of black holes in modern astrophysics Revista Mexicana de Astronomía Y Astrofísica ,1995 *IAU Colloquium 194* Gagrik Tovmassian,Edward M. Sion,2004 *Science* John Michels (Journalist),2011

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