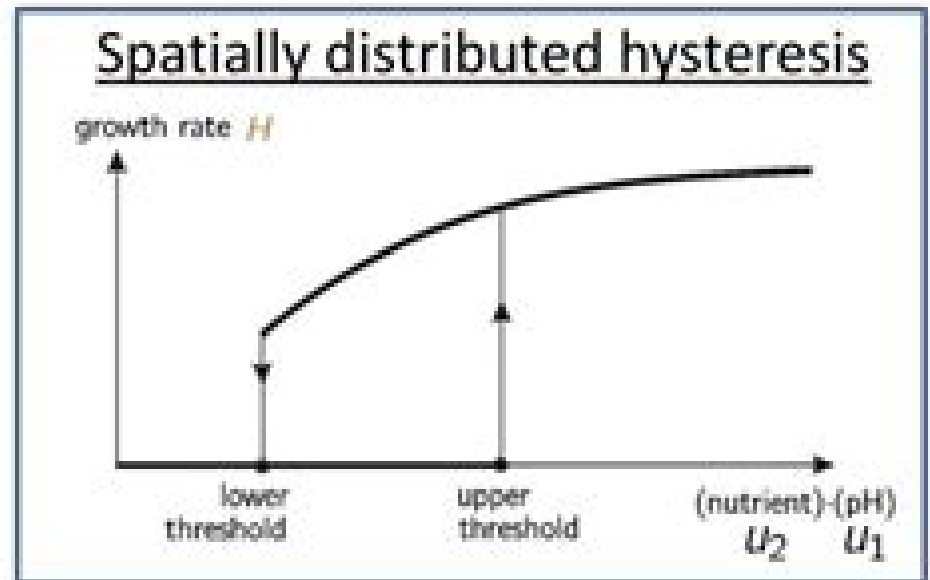


# Reaction-diffusion equations

$$\begin{cases} \frac{\partial B}{\partial t} = aHB, \\ \frac{\partial u_1}{\partial t} = D_1 \Delta u_1 - a_1 HB, \\ \frac{\partial u_2}{\partial t} = D_2 \Delta u_2 - a_2 HB. \end{cases}$$



- $a, a_1, a_2, D_1, D_2$  – given constants
- $B(x, t)$  – density of bacteria
- $u_1(x, t)$  – pH-level
- $u_2(x, t)$  – nutrient
- $H(u_1, u_2)(x, t)$  – spatially distributed hysteresis

# Reaction Diffusion Equations

**Joel Smoller**



## Reaction Diffusion Equations:

**Reaction-Diffusion Equations and Propagation Phenomena** Henri Berestycki, Francois Hamel, 2007-01-01 The book is about reaction diffusion equations in unbounded domains with a special emphasis on traveling waves and their generalizations as well as on different notions of propagation It includes a general presentation of all the classical results in this area Even for some well known results in some cases original proofs are included which are simpler and more elegant than the known ones The book gives a fairly comprehensive and coherent account of the recent developments and current research in this active area It also contains some of the basic results about elliptic and parabolic partial differential equations and a chapter on the different versions of the maximum principles Thus it also serves as an introduction to these topics Each chapter is made as much autonomous as possible Each one has a specific introduction as well as brief mentions of extensions or of related subjects Some outstanding open problems are mentioned along the way Each introduction states the goals of the chapter some of its main results the framework and indicates how the chapter is organized The book is addressed to researchers and graduate students in mathematics in particular in analysis partial differential equations and applied mathematics It will be of interest as well to researchers and graduate students concerned by mathematical modeling in physics and in biology It is planned to be a reference book of lasting value with all the important results on a topic which is commonly used in these fields

Introduction to Reaction-Diffusion Equations King-Yeung Lam, Yuan Lou, 2022-12-01 This book introduces some basic mathematical tools in reaction diffusion models with applications to spatial ecology and evolutionary biology It is divided into four parts The first part is an introduction to the maximum principle the theory of principal eigenvalues for elliptic and periodic parabolic equations and systems and the theory of principal Floquet bundles The second part concerns the applications in spatial ecology We discuss the dynamics of a single species and two competing species as well as some recent progress on  $N$  competing species in bounded domains Some related results on stream populations and phytoplankton populations are also included We also discuss the spreading properties of a single species in an unbounded spatial domain as modeled by the Fisher KPP equation The third part concerns the applications in evolutionary biology We describe the basic notions of adaptive dynamics such as evolutionarily stable strategies and evolutionary branching points in the context of a competition model of stream populations We also discuss a class of selection mutation models describing a population structured along a continuous phenotypical trait The fourth part consists of several appendices which present a self contained treatment of some basic abstract theories in functional analysis and dynamical systems Topics include the Krein Rutman theorem for linear and nonlinear operators as well as some elements of monotone dynamical systems and abstract competition systems Most of the book is self contained and it is aimed at graduate students and researchers who are interested in the theory and applications of reaction diffusion equations

*Reaction-diffusion Equations And Their Applications And Computational Aspects - Proceedings Of The China-japan Symposium* Tatsien Li, M

Mimura, Yasumasa Nishiura, Q X Ye, 1997-02-03 The aim of the symposium was to provide a forum for presenting and discussing recent developments and trends in Reaction diffusion Equations and to promote scientific exchanges among mathematicians in China and in Japan especially for the younger generation The topics discussed were Layer dynamics Traveling wave solutions and its stability Equilibrium solutions and its limit behavior stability Bifurcation phenomena Computational solutions and Infinite dimensional dynamical system **Patterns and Waves** Peter Grindrod, 1996

**Shock Waves and Reaction—Diffusion Equations** Joel Smoller, 2012-12-06 For this edition a number of typographical errors and minor slip ups have been corrected In addition following the persistent encouragement of Olga Oleinik I have added a new chapter Chapter 25 which I titled Recent Results This chapter is divided into four sections and in these I have discussed what I consider to be some of the important developments which have come about since the writing of the first edition Section I deals with reaction diffusion equations and in it are described both the work of C Jones on the stability of the travelling wave for the Fitz Hugh Nagumo equations and symmetry breaking bifurcations Section II deals with some recent results in shock wave theory The main topics considered are L Tartar s notion of compensated compactness together with its application to pairs of conservation laws and T P Liu s work on the stability of viscous profiles for shock waves In the next section Conley s connection index and connection matrix are described these general notions are useful in constructing travelling waves for systems of nonlinear equations The final section Section IV is devoted to the very recent results of C Jones and R Gardner whereby they construct a general theory enabling them to locate the point spectrum of a wide class of linear operators which arise in stability problems for travelling waves Their theory is general enough to be applicable to many interesting reaction diffusion systems Recent Progress on Reaction-diffusion Systems and Viscosity Solutions

Yihong Du, 2009 This book consists of survey and research articles expanding on the theme of the OC International Conference on Reaction Diffusion Systems and Viscosity Solutions OCO held at Providence University Taiwan during January 30 Co6 2007 It is a carefully selected collection of articles representing the recent progress of some important areas of nonlinear partial differential equations The book is aimed for researchers and postgraduate students who want to learn about or follow some of the current research topics in nonlinear partial differential equations The contributors consist of international experts and some participants of the conference including Nils Ackermann Mexico Chao Nien Chen Taiwan Yihong Du Australia Alberto Farina France Hitoshi Ishii Japan N Ishimura Japan Shigeaki Koike Japan Chu Pin Lo Taiwan Peter Polacik USA Kunimochi Sakamoto Japan Richard Tsai USA Mingxin Wang China Yoshio Yamada Japan Eiji Yanagida Japan and Xiao Qiang Zhao Canada **Nonlinear Reaction-Diffusion Systems** Roman Cherniha, Vasyli'

Davydovych, 2017-09-18 This book presents several fundamental results in solving nonlinear reaction diffusion equations and systems using symmetry based methods Reaction diffusion systems are fundamental modeling tools for mathematical biology with applications to ecology population dynamics pattern formation morphogenesis enzymatic reactions and chemotaxis The

book discusses the properties of nonlinear reaction diffusion systems which are relevant for biological applications from the symmetry point of view providing rigorous definitions and constructive algorithms to search for conditional symmetry a nontrivial generalization of the well known Lie symmetry of nonlinear reaction diffusion systems In order to present applications to population dynamics it focuses mainly on two and three component diffusive Lotka Volterra systems While it is primarily a valuable guide for researchers working with reaction diffusion systems and those developing the theoretical aspects of conditional symmetry conception parts of the book can also be used in master s level mathematical biology courses

**Reaction-diffusion Equations and Their Applications to Biology** N. F. Britton, 1986 Although the book is largely self contained some knowledge of the mathematics of differential equations is necessary Thus the book is intended for mathematicians who are interested in the application of their subject to the biological sciences and for biologists with some mathematical training It is also suitable for postgraduate mathematics students and for undergraduate mathematicians taking a course in mathematical biology Increasing use of mathematics in developmental biology ecology physiology and many other areas in the biological sciences has produced a need for a complete mathematical reference for laboratory practice In this volume biological scientists will find a rich resource of interesting applications and illustrations of various mathematical techniques that can be used to analyze reaction diffusion systems Concepts covered here include systems of ordinary differential equations conservative systems the scalar reaction diffusion equation analytic techniques for systems of parabolic partial differential equations bifurcation theory asymptotic methods for oscillatory systems singular perturbations macromolecular carriers asymptotic techniques

**A Closer Look of Nonlinear Reaction-Diffusion Equations**  
Lakshmanan Rajendran, R. Swaminathan, 2020-10 By using mathematical models to describe the physical biological or chemical phenomena one of the most common results is either a differential equation or a system of differential equations together with the correct boundary and initial conditions The determination and interpretation of their solution are at the base of applied mathematics Hence the analytical and numerical study of the differential equation is very much essential for all theoretical and experimental researchers and this book helps to develop skills in this area Recently non linear differential equations were widely used to model many of the interesting and relevant phenomena found in many fields of science and technology on a mathematical basis This problem is to inspire them in various fields such as economics medical biology plasma physics particle physics differential geometry engineering signal processing electrochemistry and materials science This book contains seven chapters and practical applications to the problems of the real world The first chapter is specifically for those with limited mathematical background Chapter one presents the introduction of non linear reaction diffusion systems various boundary conditions and examples Real life application of non linear reaction diffusion in different fields with some important non linear equations is also discussed In Chapter 2 mathematical preliminaries and various advanced methods of solving non linear differential equations such as Homotopy perturbation method variational iteration method

exponential function method etc are described with examples Steady and non steady state reaction diffusion equations in the plane sheet chapter 3 cylinder chapter 4 and spherical chapter 5 are analyzed The analytical results published by various researchers in referred journals during 2007 2020 have been addressed in these chapters 4 to 6 and this leads to conclusions and recommendations on what approaches to use on non linear reaction diffusion equations Convection diffusion problems arise very often in applied sciences and engineering Non linear convection diffusion equations and corresponding analytical solutions in various fields of chemical sciences are discussed in chapter 6 Numerical methods are used to provide approximate results for the non linear problems and their importance is felt when it is impossible or difficult to solve a given problem analytically Chapter 7 identifies some of the numerical methods for finding solutions to non linear differential equations

**Reaction-diffusion Equations** K. J. Brown, A. A. Lacey, Heriot-Watt University. Department of Mathematics, 1990 Reaction diffusion equations may be applied to a wide variety of scientific phenomena Some of these articles survey particular applications in combustion theory electro chemistry cellular neurobiology and population dynamics Others analyze the general structure of the equations

**The Dynamics of Nonlinear Reaction-Diffusion Equations with Small Lévy Noise** Arnaud Debussche, Michael Högele, Peter Imkeller, 2013-10-01 This work considers a small random perturbation of alpha stable jump type nonlinear reaction diffusion equations with Dirichlet boundary conditions over an interval It has two stable points whose domains of attraction meet in a separating manifold with several saddle points Extending a method developed by Imkeller and Pavlyukevich it proves that in contrast to a Gaussian perturbation the expected exit and transition times between the domains of attraction depend polynomially on the noise intensity in the small intensity limit Moreover the solution exhibits metastable behavior there is a polynomial time scale along which the solution dynamics correspond asymptotically to the dynamic behavior of a finite state Markov chain switching between the stable states

**Nonlinear Reaction-Diffusion-Convection Equations** Roman Cherniha, Mykola Serov, Oleksii Pliukhin, 2017-11-02 It is well known that symmetry based methods are very powerful tools for investigating nonlinear partial differential equations PDEs notably for their reduction to those of lower dimensionality e g to ODEs and constructing exact solutions This book is devoted to 1 search Lie and conditional non classical symmetries of nonlinear RDC equations 2 constructing exact solutions using the symmetries obtained and 3 their applications for solving some biologically and physically motivated problems The book summarises the results derived by the authors during the last 10 years and those obtained by some other authors

Traveling Front Solutions in Reaction-Diffusion Equations Masaharu Taniguchi, 2021-05-28 The study on traveling fronts in reaction diffusion equations is the first step to understand various kinds of propagation phenomena in reaction diffusion models in natural science One dimensional traveling fronts have been studied from the 1970s and multidimensional ones have been studied from around 2005 This volume is a text book for graduate students to start their studies on traveling fronts Using the phase plane analysis we study the existence of traveling fronts in

several kinds of reaction diffusion equations For a nonlinear reaction term a bistable one is a typical one For a bistable reaction diffusion equation we study the existence and stability of two dimensional V form fronts and we also study pyramidal traveling fronts in three or higher space dimensions The cross section of a pyramidal traveling front forms a convex polygon It is known that the limit of a pyramidal traveling front gives a new multidimensional traveling front For the study the multidimensional traveling front studying properties of pyramidal traveling fronts plays an important role In this volume we study the existence uniqueness and stability of a pyramidal traveling front as clearly as possible for further studies by graduate students For a help of their studies we briefly explain and prove the well posedness of reaction diffusion equations and the Schauder estimates and the maximum principles of solutions Published by Mathematical Society of Japan and distributed by World Scientific Publishing Co for all markets *Shock Waves and Reaction-diffusion Equations* Joel Smoller,1994-01-01

**Systems of Reaction-diffusion Equations and Their Attractors** Matthias Bürger,2005 **Shock**

**Waves and Reaction-Diffusion Equations** J. Smoller,2012 The progress of physics will to a large extent depend on the progress of nonlinear mathematics of methods to solve nonlinear equations and therefore we can learn by comparing different nonlinear problems WERNER HEISENBERG I undertook to write this book for two reasons First I wanted to make easily available the basics of both the theory of hyperbolic conservation laws and the theory of systems of reaction diffusion equations including the generalized Morse theory as developed by C Conley These important subjects seem difficult to learn since the results are scattered throughout the research journals 1 Second I feel that there is a need to present the modern methods and ideas in these fields to a wider audience than just mathematicians Thus the book has some rather sophisticated aspects to it as well as certain textbook aspects The latter serve to explain somewhat the reason that a book with the title Shock Waves and Reaction Diffusion Equations has the first nine chapters devoted to linear partial differential equations More precisely I have found from my classroom experience that it is far easier to grasp the subtleties of nonlinear partial differential equations after one has an understanding of the basic notions in the linear theory This book is divided into four main parts linear theory reaction diffusion equations shock wave theory and the Conley index in that order Thus the text begins with a discussion of ill posed problems *Variational Convergence And Stochastic Homogenization Of Nonlinear Reaction-diffusion Problems* Omar Anza Hafsa,Jean-philippe Mandallena,Gerard Michaille,2022-06-21

A substantial number of problems in physics chemical physics and biology are modeled through reaction diffusion equations to describe temperature distribution or chemical substance concentration For problems arising from ecology sociology or population dynamics they describe the density of some populations or species In this book the state variable is a concentration or a density according to the cases The reaction function may be complex and include time delays terms that model various situations involving maturation periods resource regeneration times or incubation periods The dynamics may occur in heterogeneous media and may depend upon a small or large parameter as well as the reaction term From a purely formal

perspective these parameters are indexed by  $n$  Therefore reaction diffusion equations give rise to sequences of Cauchy problems The first part of the book is devoted to the convergence of these sequences in a sense made precise in the book The second part is dedicated to the specific case when the reaction diffusion problems depend on a small parameter intended to tend towards 0 This parameter accounts for the size of small spatial and randomly distributed heterogeneities The convergence results obtained in the first part with additionally some probabilistic tools are applied to this specific situation The limit problems are illustrated through biological invasion food limited or prey predator models where the interplay between environment heterogeneities in the individual evolution of propagation species plays an essential role They provide a description in terms of deterministic and homogeneous reaction diffusion equations for which numerical schemes are possible

**The Dynamics of Nonlinear Reaction-Diffusion Equations with Small Levy Noise** Arnaud

Debussche, Michael Hogele, Peter Imkeller, 2013-09-30

Numerical Bifurcation Analysis for Reaction-Diffusion Equations

Zhen Mei, 2000-06-21 This monograph is the first to provide readers with numerical tools for a systematic analysis of bifurcation problems in reaction diffusion equations Many examples and figures illustrate analysis of bifurcation scenario and implementation of numerical schemes Readers will gain a thorough understanding of numerical bifurcation analysis and the necessary tools for investigating nonlinear phenomena in reaction diffusion equations

**Estimating the Error of**

**Numerical Solutions of Systems of Reaction-Diffusion Equations** Donald J. Estep, Mats G. Larson, Roy D. Williams, 2000

This paper is concerned with the computational estimation of the error of numerical solutions of potentially degenerate reaction diffusion equations The underlying motivation is a desire to compute accurate estimates as opposed to deriving inaccurate analytic upper bounds In this paper we outline analyze and test an approach to obtain computational error estimates based on the introduction of the residual error of the numerical solution and in which the effects of the accumulation of errors are estimated computationally We begin by deriving an a posteriori relationship between the error of a numerical solution and its residual error using a variational argument This leads to the introduction of stability factors which measure the sensitivity of solutions to various kinds of perturbations Next we perform some general analysis on the residual errors and stability factors to determine when they are defined and to bound their size Then we describe the practical use of the theory to estimate the errors of numerical solutions computationally Several key issues arise in the implementation that remain unresolved and we present partial results and numerical experiments about these points We use this approach to estimate the error of numerical solutions of nine standard reaction diffusion models and make a systematic comparison of the time scale over which accurate numerical solutions can be computed for these problems We also perform a numerical test of the accuracy and reliability of the computational error estimate using the bistable equation Finally we apply the general theory to the class of problems that admit invariant regions for the solutions which includes seven of the main examples Under this additional stability assumption we obtain a convergence result in the form of an upper bound on the



error from the a posteriori error estimate We conclude by discussing the preservation of invariant regions under discretization

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