

# Gravitational waves from phase transitions in scale invariant models

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**ABSTRACT:** We investigate the properties of the gravitational waves (GW) generated during a strongly first order electroweak phase transition (EWPT) in models with the classical scale invariance (CSI). Here, we distinguish two parameter space regions that correspond to the cases of (1) light dilaton and (2) purely radiative Higgs mass (PRHM). In the CSI models, the dilaton mass, or the Higgs mass in the PRHM case, in addition to some triple scalar couplings are fully triggered by the radiative corrections (RCs). In order to probe the RC effects on the EWPT strength and on the GW spectrum, we extend the standard model by a real singlet to assist the electroweak symmetry breaking and an additional scalar field  $Q$  with multiplicity  $N_Q$  and mass  $m_Q$ . After imposing all theoretical and experimental constraints, we show that a strongly first order EWPT with detectable GW spectra can be realized for the two cases of light dilaton and PRHM. We also show the corresponding values of the relative enhancement of the cross section for the di-Higgs production process, which is related to the triple Higgs boson coupling. We obtain the region in which the GW spectrum can be observed by different future experiments such as LISA and DECIGO. We also show that the scenarios (1) and (2) can be discriminated by future GW observations and measurements of the di-Higgs productions at future colliders.

**KEYWORDS:** Cosmology of Theories BSM, Multi-Higgs Models, Phase Transitions in the Early Universe

**ARXIV EPRINT:** [2308.12676](https://arxiv.org/abs/2308.12676)

# Models Of Phase Transitions

**Alexandra Quitmann**



## **Models Of Phase Transitions:**

Models of Phase Transitions Augusto Visintin,1996

**Models of Phase Transitions** Augusto Visintin,2011-10-29

*Mathematical Methods and Models in Phase Transitions* Alain Miranville,2005 The modelling and the study of phase transition phenomena are capital issues as they have essential applications in material sciences and in biological and industrial processes We can mention e g phase separation in alloys ageing of materials microstructure evolution crystal growth solidification in complex alloys surface diffusion in the presence of stress evolution of the surface of a thin flow in heteroepitaxial growth motion of voids in interconnects in integrated circuits treatment of airway closure disease by surfactant injection fuel injection fire extinguishers etc This book consists of 11 contributions from specialists in the mathematical modelling and analysis of phase transitions The content of these contributions ranges from the modelling to the mathematical and numerical analysis Furthermore many numerical simulations are presented Finally the contributors have tried to give comprehensive and accurate reference lists This book should thus serve as a reference book for researchers interested in phase transition phenomena

### **Continuum Models for Phase Transitions and Twinning in Crystals**

Mario Pitteri,G. Zanzotto,2002-06-27 Continuum Models for Phase Transitions and Twinning in Crystals presents the fundamentals of a remarkably successful approach to crystal thermomechanics Developed over the last two decades it is based on the mathematical theory of nonlinear thermoelasticity in which a new viewpoint on material symmetry motivated by molecular theories plays a c

*Mathematical Methods and Models in Phase Transitions* ,2006

**Statistical Mechanics of Phase Transitions** J. M. Yeomans,1992-05-07 The book provides an introduction to the physics which underlies phase transitions and to the theoretical techniques currently at our disposal for understanding them It will be useful for advanced undergraduates for post graduate students undertaking research in related fields and for established researchers in experimental physics chemistry and metallurgy as an exposition of current theoretical understanding Recent developments have led to a good understanding of universality why phase transitions in systems as diverse as magnets fluids liquid crystals and superconductors can be brought under the same theoretical umbrella and well described by simple models This book describes the physics underlying universality and then lays out the theoretical approaches now available for studying phase transitions Traditional techniques mean field theory series expansions and the transfer matrix are described the Monte Carlo method is covered and two chapters are devoted to the renormalization group which led to a breakthrough in the field The book will be useful as a textbook for a course in Phase Transitions as an introduction for graduate students undertaking research in related fields and as an overview for scientists in other disciplines who work with phase transitions but who are not aware of the current tools in the armoury of the theoretical physicist Introduction Statistical mechanics and thermodynamics Models Mean field theories The transfer matrix Series expansions Monte Carlo simulations The renormalization group Implementations of the renormalization group

### **Nonequilibrium Phase Transitions in Lattice**

**Models** Joaquin Marro,Ronald Dickman,1999-05-06 This book provides an introduction to nonequilibrium statistical physics via lattice models Beginning with an introduction to the basic driven lattice gas the early chapters discuss the relevance of this lattice model to certain natural phenomena examining simulation results in detail Later chapters discuss absorbing state transitions and examine a variety of systems subject to dynamic disorder The book discusses the effects of multiparticle rules nonunique absorbing states and conservation laws as well as the use of methods such as mean field theory Monte Carlo simulation and the concept of universality It also includes detailed references and examples using simple representations of nature to describe real systems

Phase Transitions For Beginners Sergei M Stishov,2018-10-02 Written by an experimentalist famous for his discovery of stishovite with vast experience in phase transition studies this book is devoted to a description of the continuous and discontinuous phase transitions It includes chapters outlining the Van der Waals model hard sphere and soft sphere models of melting scaling phenomena renormgroup approach to phase transitions and experimental examples to illustrate various phase transitions Unlike conventional books covering the same topic this is meant for undergraduate students and experimentalists to understand basic concepts in the physics of phase transitions

Application of Integrable Systems to Phase Transitions C.B. Wang,2013-07-20 The eigenvalue densities in various matrix models in quantum chromodynamics QCD are ultimately unified in this book by a unified model derived from the integrable systems Many new density models and free energy functions are consequently solved and presented The phase transition models including critical phenomena with fractional power law for the discontinuities of the free energies in the matrix models are systematically classified by means of a clear and rigorous mathematical demonstration The methods here will stimulate new research directions such as the important Seiberg Witten differential in Seiberg Witten theory for solving the mass gap problem in quantum Yang Mills theory The formulations and results will benefit researchers and students in the fields of phase transitions integrable systems matrix models and Seiberg Witten theory

**Phase Transitions of Simple Systems** Boris M. Smirnov,Stephen R. Berry,2007-10-24 Thermodynamic concepts of aggregate states and their phase transitions developed during the 19th Century and are now the basis of our contemporary understanding of these phenomena Thermodynamics gives an universal macroscopic description of the equilibrium properties of phase transitions dependent of the detailed nature of the substances However understanding the nature of phase transitions at the microscopic level requires a different approach one that takes into account the specifics of the interparticle interactions In this book we lay the groundwork that connects the microscopic phenomena underlying phase changes with the macroscopic picture but in a somewhat restricted way We deal only with systems in which electronic excitations are not important only with atomic systems and only with homogeneous systems We also restrict our analysis to systems in which only pairwise interactions need be included and in many parts of the treatment to systems in which one need consider only the interactions between nearest neighbor atoms In establishing these restrictions we can be guided by the solid and liquid states of inert gases and the phase

transitions between them although the subsequent analysis is relevant and applicable for a series of other physical systems To study the behavior of a system of many interacting identical particles we work extensively with its potential energy surface PES a surface in a many dimensional space whose independent variables are the monomer coordinates or some transformation thereof A central property of any multidimensional PES is its large number of local minima

**Dissipative Phase Transitions** Pierluigi Colli, Nobuyuki Kenmochi, Jurgen Sprekels, 2006-03-06 Phase transition phenomena arise in a variety of relevant real world situations such as melting and freezing in a solid liquid system evaporation solid solid phase transitions in shape memory alloys combustion crystal growth damage in elastic materials glass formation phase transitions in polymers and plasticity The practical interest of such phenomenology is evident and has deeply influenced the technological development of our society stimulating intense mathematical research in this area This book analyzes and approximates some models and related partial differential equation problems that involve phase transitions in different contexts and include dissipation effects

*Phase Transitions and Critical Phenomena*, 2000-09-15 The field of phase transitions and critical phenomena continues to be active in research producing a steady stream of interesting and fruitful results No longer an area of specialist interest it has acquired a central focus in condensed matter studies The major aim of this series is to provide review articles that can serve as standard references for research workers in the field and for graduate students and others wishing to obtain reliable information on important recent developments The two review articles in this volume complement each other in a remarkable way Both deal with what might be called the modern geometric approach to the properties of macroscopic systems The first article by Georgii et al describes how recent advances in the application of geometric ideas leads to a better understanding of pure phases and phase transitions in equilibrium systems The second article by Alava et al deals with geometrical aspects of multi body systems in a hands on way going beyond abstract theory to obtain practical answers The combination of computers and geometrical ideas described in this volume will doubtless play a major role in the development of statistical mechanics in the twenty first century

**Mathematical Models for Phase Change Problems** J.F. Rodrigues, 1989-09-01 Mathematical Models in Phase Transitions Hans Wilhelm Alt, Paul C. Fife, 1995

**Probability and Phase Transition** G.R. Grimmett, 2013-04-17 This volume describes the current state of knowledge of random spatial processes particularly those arising in physics The emphasis is on survey articles which describe areas of current interest to probabilists and physicists working on the probability theory of phase transition Special attention is given to topics deserving further research The principal contributions by leading researchers concern the mathematical theory of random walk interacting particle systems percolation Ising and Potts models spin glasses cellular automata quantum spin systems and metastability The level of presentation and review is particularly suitable for postgraduate and postdoctoral workers in mathematics and physics and for advanced specialists in the probability theory of spatial disorder and phase transition

**New Kinds of Phase Transitions: Transformation in Disordered Substances**

V.V. Brazhkin, 2002-08-31 Proceedings of the NATO Advanced Research Workshop held in Volga River Russia 24-28 May 2001 PDEs and Continuum Models of Phase Transitions M. Rascle, 1989 In three well organized sections this book offers the first detailed survey of dispersion compensating fibers The sections outline Conventional Dispersion Compensating Fiber including a chapter on modeling dispersion in optical fibers Alternative and Emerging Technologies including control of dispersion in photonic crystal fibers and Systems experiments and Impacts featuring a survey of systems experiments demonstrating Dispersion Compensation Technologies **Phase Transitions in Random Loop Models** Alexandra Quitmann, 2023 *Lattice Models and Conformal Field Theory* Franck Gabriel, Clément Hongler, Francesco Spadaro, 2024-08-23 This book introduces the mathematical ideas connecting Statistical Mechanics and Conformal Field Theory CFT Building advanced structures on top of more elementary ones the authors map out a well posed road from simple lattice models to CFTs Structured in two parts the book begins by exploring several two dimensional lattice models their phase transitions and their conjectural connection with CFT Through these lattice models and their local fields the fundamental ideas and results of two dimensional CFTs emerge with a special emphasis on the Unitary Minimal Models of CFT Delving into the delicate ideas that lead to the classification of these CFTs the authors discuss the assumptions on the lattice models whose scaling limits are described by CFTs This produces a probabilistic rather than an axiomatic or algebraic definition of CFTs Suitable for graduate students and researchers in mathematics and physics *Lattice Models and Conformal Field Theory* introduces the ideas at the core of Statistical Field Theory Assuming only undergraduate probability and complex analysis the authors carefully motivate every argument and assumption made Concrete examples and exercises allow readers to check their progress throughout **Phase Transitions and Critical Phenomena** Cyril Domb, Melville S. Green, 1972

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