

Review

Symmetries and Asymmetries in Branching Processes

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Abstract: As is known in stochastic particle theory, the same random process can be described by two different master equations for the evolution of the probability density, namely, by a forward or a backward master equations. These are the generalised analogues of the direct and adjoint equations of traditional transport theory. At the level of the first moment, these two equations show considerable resemblance to each other, but they become increasingly different with increasing moment order. The purpose of this paper is to demonstrate this increasing asymmetry and to discuss the underlying reasons. It is argued that since the reason of the different forms of the forward and the backward equations lies in the lack of invariance of the process to time reversal, the reason for the increasing asymmetry between the two forms for higher-order moments or processes with several variables (particle types) can be related to the increasing level of the violation of the invariance to time reversal, as is illustrated with some examples.

Keywords: branching processes; stochastic transport; master equations; forward equation; backward equation; Chapman–Kolmogorov

1. Introduction

Neutron transport in a multiplying (fissile) medium is a branching process. It has been known ever since the theory of the extinction of family trees was formulated [1,2], that branching processes, in which an entity can give rise to a random number of secondaries, might show significant fluctuations. It is also known [3–5], that both the traditional (deterministic) neutron transport equation, as well as the master equations for the probability distribution, or the higher-order moments of the neutron population, can be derived both from a direct (forward) and an adjoint (backward) approach. The corresponding equations are different, even if their solutions, at the level of the Green's function, are identical. The relationship between the forward and backward equations has been discussed substantially in the literature [6–9].

At the level of expectations, i.e., traditional deterministic neutron transport, the direct and adjoint forward equations, although different, still show a considerable resemblance to each other, with expressed symmetry properties. The reason for the differences between the forward and backward, or direct and adjoint forms, is that the underlying physical processes are not invariant for a time reversal, which is a kind of symmetry breaking. As is known, for the deterministic neutron transport equation, the lack of the invariance lies partly in the boundary condition (particles only leave the system but do not enter it from the outside), and partly in the irreversibility of the scattering process. This asymmetry is though “mild”, the boundary condition is not even reflected in the equation itself, and therefore, the direct and adjoint equations are reasonably similar to each other.

It is also known, however, that the forward and backward forms become increasingly different in structure, even for purely time-dependent processes, when turning to the higher-order statistical moments of the process. The difference further increases when considering more involved processes, such as a branching process with several different particle types, or considering a branching process on the phase space (i.e., including space,



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Symmetries Asymmetries

C E Horne



Symmetries Asymmetries:

Symmetries, Asymmetries, and the World of Particles T. D. Lee, 1988 Discusses mirror symmetry a symmetries time reversal vacuum as a physical medium spontaneous symmetry breaking particles and quarks Gauge Symmetries, Symmetry Breaking, and Gauge-Invariant Approaches Philipp Berghofer, Jordan François, Simon Friederich, Henrique Gomes, Guy Hetzroni, Axel Maas, René Sondenheimer, 2023-08-03 Gauge symmetries play a central role both in the mathematical foundations as well as the conceptual construction of modern particle physics theories However it is yet unclear whether they form a necessary component of theories or whether they can be eliminated It is also unclear whether they are merely an auxiliary tool to simplify and possibly localize calculations or whether they contain independent information Therefore their status both in physics and philosophy of physics remains to be fully clarified This Element reviews the current state of affairs on both the philosophy and the physics side In particular it focuses on the circumstances in which the restriction of gauge theories to gauge invariant information on an observable level is warranted using the Brout Englert Higgs theory as an example of particular current importance Finally the authors determine a set of yet to be answered questions to clarify the status of gauge symmetries Symmetry György Darvas, 2007-02-15 The first comprehensive book on the topic in half a century explores recent symmetry and symmetry breaking related discoveries and discusses the questions and answers they raise in diverse disciplines particle and high energy physics structural chemistry and the biochemistry of proteins in genetic code study in brain research and also in architectural structures and business decision making to mention only a few examples **Symmetry Rules** Joseph Rosen, 2008-02-20 When we use science to describe and understand the world around us we are in essence grasping nature through symmetry Emphasizing the concepts this book leads the reader coherently and comprehensively into the fertile field of symmetry and its applications Among the most important applications considered are the fundamental forces of nature and the Universe Written by a renowned expert this book will convince all interested readers of the importance of symmetry in science **The Symmetry Perspective** Martin Golubitsky, Ian Stewart, 2002-01-01 The framework of symmetry provides an important route between the abstract theory and experimental observations The book applies symmetry methods to dynamical systems focusing on bifurcation and chaos theory Its exposition is organized around a wide variety of relevant applications From the reviews The rich collection of examples makes the book extremely useful for motivation and for spreading the ideas to a large Community MATHEMATICAL REVIEWS **Symmetry in health and illness** Mykola Iabluchanskyi, Andriy Yabluchanskiy, 2024-11-14 Symmetry is one of the fundamental principles that organize not only the inanimate nature but also various aspects of the living including the structure and functioning of the human organism This book explores how symmetry permeates all levels of biological organization from molecular to systemic and plays a critical role in maintaining health and regulating processes during illness Using examples of mirror central rotational mirror rotational translational symmetries and glide plane

symmetry we demonstrate how these regularities affect physiological functions the preservation of homeostasis and the organism's adaptability to external and internal changes Chapters are also dedicated to symmetry in the mental and social spheres showing how these universal laws manifest not only in organic structures but also in the emotional and social life of humans The principle of symmetry in therapy is considered as a tool for understanding disease mechanisms and constructing optimal treatment approaches Identifying and correcting asymmetries can enhance the effectiveness of therapeutic interventions A separate chapter is devoted to the principle of symmetry in the encoding of life where symmetry is presented as a mechanism that allows compact storage and transmission of genetic information The book calls for a deeper understanding of symmetry as a key factor in the harmonious organization and functioning of the human organism which forms the basis for the latest scientific approaches in medical science and practice Symmetry as a Developmental Principle in Nature and Art Werner Hahn, 1998 Looking beyond the boundaries of various disciplines the author demonstrates that symmetry is a fascinating phenomenon which provides endless stimulation and challenges He explains that it is possible to readapt art to the sciences and vice versa by means of an evolutionary concept of symmetry Many pictorial examples are included to enable the reader to fully understand the issues discussed Based on the artistic evidence that the author has collected he proposes that the new ars evolutoria can function as an example for the sciences The book is divided into three distinct parts each one focusing on a special issue In Part I the phenomenon of symmetry including its discovery and meaning is reviewed The author looks closely at how Vitruvius Polyclitus Democritus Plato Aristotle Plotinus Augustine Alberti Leonardo da Vinci and Durer viewed symmetry This is followed by an explanation on how the concept of symmetry developed The author further discusses symmetry as it appears in art and science as well as in the modern age Later he expounds the view of symmetry as an evolutionary concept which can lead to a new unity of science In Part II he covers the points of contact between the form developing process in nature and art He deals with biological questions in particular evolution The collection of new and precise data on perception and knowledge with regard to the postulated reality of symmetry leads to further development of the evolutionary theory of symmetry in Part III The author traces the enormous treasure of observations made in nature and culture back to a few underlying structural principles He demonstrates symmetry as a far reaching leading structuring causal element of evolution as the idea lying behind nature and culture Numerous controllable reproducible double mirror experiments on a new stereoscopic vision verify a symmetrization theory of perception *Explicit Symmetry Breaking in Electrodynamical Systems and Electromagnetic Radiation* Dhiraj Sinha, Gehan A J Amaratunga, 2016-04-01 This book is an introduction to the concept of symmetries in electromagnetism and explicit symmetry breaking It begins with a brief background on the origin of the concept of symmetry and its meaning in fields such as architecture mathematics and physics Despite the extensive developments of symmetry in these fields it has yet to be applied to the context of classical electromagnetism and related engineering applications This book unravels the beauty and

excitement of this area to scientists and engineers

Geometric Symmetry in Patterns and Tilings C E

Horne,2000-10-23 This book covers a wide range of mathematical concepts as they are applied to regularly repeating surface decoration for textiles and other decorated materials such as wallpapers and wrappings Starting with basic principles of symmetry it moves on to cover more complex issues of graph theory group theory and topology All these concepts are extensively illustrated with over 1000 original illustrations A complex area previously best understood by mathematicians and crystallographers is made accessible here to artists and designers

Symmetries in Physics Katherine Brading,Elena Castellani,2003-12-04 Symmetry considerations dominate modern fundamental physics both in quantum theory and in relativity This book presents a collection of philosophy on physics papers highlighting the main issues and controversies and providing an entry into the subject for both physicists and philosophers It covers topical issues such as the significance of gauge symmetry particle identity in quantum theory how to make sense of parity violation the role of symmetry breaking the empirical status of symmetry principles and so forth along with more traditional problems in the philosophy of science These include the status of the laws of nature the relationships between mathematics physical theory and the world and the extent to which mathematics dictates physics A valuable reference for students and researchers it will also be of interest to those studying the foundations of physics philosophy of physics and philosophy of science

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