

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,



Citation: Pázsit, I. Symmetries and Asymmetries in Branching Processes. *Symmetry* **2023**, *15*, 1154. <https://doi.org/10.3390/sym15061154>

Academic Editor: Vladimír García-Morales

Received: 31 March 2023

Revised: 3 May 2023

Accepted: 25 May 2023

Published: 26 May 2023



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Symmetries Asymmetries

T. D. Lee



Symmetries Asymmetries:

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