



# The Evolutionary Versus the All-at-Once Picture of Spacetime

M. Ebrahim Maghsoudi<sup>1</sup> · Seyed Ali Taheri Khorramabadi<sup>1</sup>

Received: 30 May 2024 / Accepted: 29 August 2024

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2024

## Abstract

There are two metaphysical pictures of spacetime: The evolutionary picture and the all-at-once picture. According to the evolutionary picture, spacetime is nothing but the evolution of space over time. In contrast, the all-at-once picture considers spacetime as ‘a global, four-dimensional boundary value problem’ that can be solved only in an all-at-once manner, i.e. as a whole which is fundamentally four-dimensional and non-decomposable into spatial and temporal parts. The two most-known formulations of general theory of relativity, i.e. the Hamiltonian (or the canonical) and the Lagrangian (or the standard) formulations, enjoy the evolutionary and all-at-once pictures of spacetime respectively. Here, we have argued that (1) the all-at-once picture is more aligned with the philosophy of relativity theory, i.e. uniting space and time into spacetime, (2) the evolutionary picture is not as general as the all-at-once, since only in special cases, such as globally hyperbolic spacetimes, is it possible to deal with spacetime as the evolution of a spatial slice over time, and (3) the all-at-once picture paves the way to better understanding *four-dimensional* physical entities, like event horizons, which cannot be explained within an evolutionary picture without raising a paradox. Therefore, the evolutionary picture is neither the *fundamentally-true* nor the *naturally-chosen* picture of spacetime. Rather, we choose the evolutionary picture for practical and computational reasons. While the all-at-once picture seems a more appropriate description of the quantum and cosmological reality, the evolutionary picture can be applied occasionally and locally, or quasi-locally, and is not the proper metaphysical picture of spacetime at the fundamental level of reality.

**Keywords** Spacetime · The evolutionary picture · The all-at-once picture · Hamiltonian formulation · Lagrangian formulation · The event horizon

---

Extended author information available on the last page of the article