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Scalar field as an intrinsic time measure in coupled dynamical matter-geometry systems. I: Neutral gravitational collapse. (English) Zbl 1388.83026

Summary: There does not exist a notion of time which could be transferred straightforwardly from classical to quantum gravity. For this reason, a method of time quantification which would be appropriate for gravity quantization is being sought. One of the existing proposals is using the evolving matter as an intrinsic ‘clock’ while investigating the dynamics of gravitational systems. The objective of our research was to check whether scalar fields can serve as time variables during a dynamical evolution of a coupled multicomponent matter-geometry system. We concentrated on a neutral case, which means that the elaborated system was not charged electrically nor magnetically. For this purpose, we investigated a gravitational collapse of a self-interacting complex and real scalar fields in the Brans-Dicke theory using the $2 + 2$ spacetime foliation. We focused mainly on the region of high curvature appearing nearby the emerging singularity, which is essential from the perspective of quantum gravity. We investigated several formulations of the theory for various values of the Brans-Dicke coupling constant and the coupling between the Brans-Dicke field and the matter sector of the theory. The obtained results indicated that the evolving scalar fields can be treated as time variables in close proximity of the singularity due to the following reasons. The constancy hypersurfaces of the Brans-Dicke field are spacelike in the vicinity of the singularity apart from the case, in which the equation of motion of the field reduces to the wave equation due to a specific choice of free evolution parameters. The hypersurfaces of constant complex and real scalar fields are spacelike in the regions nearby the singularities formed during the examined process. The values of the field functions change monotonically in the areas, in which the constancy hypersurfaces are spacelike.

MSC:
83C05 Einstein’s equations (general structure, canonical formalism, Cauchy problems)

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classical theories of gravity; black holes

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References:

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