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Arrow of time in dissipationless cosmology

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Abstract

© 2015 IOP Publishing Ltd. It is generally believed that a cosmological arrow of time must be associated with entropy production. Indeed, in his seminal work on cyclic cosmology, Tolman introduced a viscous fluid in order to make successive expansion/contraction cycles larger than previous ones, thereby generating an arrow of time. However, as we demonstrate in this letter, the production of entropy is not the only means by which a cosmological arrow of time may emerge. Remarkably, systems which are dissipationless may nevertheless demonstrate a preferred direction of time provided they possess attractors. An example of a system with well defined attractors is scalar-field driven cosmology. In this case, for a wide class of potentials (especially those responsible for inflation), the attractor equation of state during expansion can have the form $\rho \simeq -\rho$, and during contraction $\rho \simeq \rho$. If the resulting cosmology is cyclic, then the presence of cosmological hysteresis, $\varphi\, pdV \neq 0$ during successive cycles, causes an arrow of time to emerge in a system which is formally dissipationless. An important analogy is drawn between the arrow of time in cyclic cosmology and an arrow of time in an N-body system of gravitationally interacting particles. We find that, like the N-body system, a cyclic Universe can evolve from a single past into two futures with oppositely directed arrows of time.

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Keywords

arrow of time, cyclic Universe, inflation, time reversal