Time glass: A fractional calculus approach

Robin C. Verstraten[1], Rodrigo F. Ozela[1,2], and Cristiane Morais Smith[1]

[1]*Institute for Theoretical Physics, Utrecht University, Princetonplein 5, 3584CC Utrecht, The Netherlands*
[2]*Faculdade de Física, Universidade Federal do Pará, 66075-110 Belém, PA, Brazil*

Out-of-equilibrium states in glasses and crystals have been a major topic of research in condensed-matter physics for many years, and the idea of time crystals has triggered a flurry of new research. Here, we provide a description for the recently conjectured time glasses using fractional calculus methods. An exactly solvable effective theory is introduced with a continuous parameter describing the transition from liquid through normal glass and time glass into the marginal glass phase. The phenomenological description with a fractional Langevin equation is connected to a microscopic model of a particle in a sub-Ohmic bath in the framework of a generalized Caldeira-Leggett model.