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Gravitational collapse of dark matter in presence of dark energy

We propose a model of the gravitational collapse of dark matter in the presence of dark energy, modeled by quintessence or phantom-like scalar fields. This work is based on the principles of general relativity up to virialization. We have chosen a spherical patch that starts to collapse gravitationally, as occurs in top-hat collapse. It is observed that although the dark matter sector collapses, the dark energy sector maintains a profile that is almost similar to the dark energy profile for the background expanding FLRW universe, given suitable model parameters. It is noted that in order to formulate the problem in the general relativistic setting, one requires an external generalized Vaidya spacetime to be matched with the internal spherical patch whose dynamics are guided by the FLRW metric. It is shown that almost all collapses are accompanied by some flux of matter and radiation in the generalized Vaidya spacetime. Some spherical regions of the Universe are observed not to collapse but to expand eternally, producing void-like structures. Whether a spherical region will collapse or expand depends on the initial values of the system and other model parameters. The evolution of the over-dense region will change if the scalar field is non-minimally coupled to the dark matter. Here we focus on algebraic coupling, where the interaction Lagrangian is independent of the derivatives of the scalar field. Our investigation reveals that an increase in the coupling strength causes dark energy to cluster with dark matter at a certain cosmological scale where the influence of dark energy cannot be ignored. This phenomenon arises from the specific nature of the non-minimal coupling considered in our work. As this work shows that collapsing structures must emit some form of radiation, this may be taken as an observational signature of our proposal.

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