Study of oscillons in 1+1D with a gentle introduction to multi-component oscillon models

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Abstract: Oscillons are long-lived field scalar configurations that are localized in space and oscillate in time. They are objects that arise in scalar field theories, when a non-linearity in the potential can balance the dispersion relations. They are non-topological and not completely stable, but nevertheless can last for thousands of oscillations. Hence they can have significant cosmological consequences, if they are formed after inflation. A number of physical phenomenon from water waves traveling in narrow canals, to phase transitions in the early Universe exhibit the formation of localized, long-lived energy density configurations, even without gravitational interactions. Some configurations are stable due to conservation of topological or nontopological charges, while some are long lived due to a dynamical balance between the nonlinearities and dissipative forces. Some well-studied examples include topological solitons in the 1 + 1-dimensional Sine-Gordon model and nontopological solitons such as Q-balls. The Sine-Gordon soliton is stationary in time, whereas the Q-balls are oscillatory in nature. Both have conserved charges, which make them stable (at least without coupling to gravity). Another interesting example of such localized configurations called oscillons (also called breathers). Like the Sine-Gordon soliton, they can exist in real scalar fields, and like the Q-balls they are oscillatory in nature. Unlike both of the above examples they do not have any known conserved charges. In general they decay, however their lifetimes are significantly longer than any natural time scales present in the Lagrangian. Along with their longevity, another fascinating aspect of oscillons is that they emerge naturally from relatively arbitrary initial conditions. Relativistic, scalar field theories (with nonlinear potentials) form simple yet interesting candidates for studying such phenomenon. While oscillons have been shown to exist in many models and their properties have been studied using various possible influence on the initial conditions, there is only a handful of papers dealing with oscillons made up of two fields (none exists for systems with more than two fields). This is an important oversight, since realistic high energy physics (e.g. string theory and supersymmetry) models are likely to include a variety of interacting scalar fields.

Goals:

1. Calculate the profile of the oscillon model in 1+1D both analytically and numerically.
2. Study the oscillon model extensively in 1+1D
3. Study the energy dessipation and decay of the oscillon profile
4. Extend the model to multi-component oscillons