Possible Oscillon Projects

Evangelos Sfakianakis[1,2]
[1] *Nikhef, Science Park 105, 1098 XG Amsterdam, The Netherlands*
[2] *Institute Lorentz of Theoretical Physics, University of Leiden, 2333CA Leiden, The Netherlands*
(Dated: October 30, 2017)

Oscillons are long-lived field configurations that are localized in space and oscillate in time. This very short note is only intended to provide some first references and context, as well as propose a few avenues of further research into oscillons.

Oscillons are objects that arise in scalar field theories, when a non-linearity in the potential can balance the dispersion. They are non-topological and not completely stable. Nevertheless they can last for thousands of oscillations, hence they can have significant cosmological consequences, if they are formed after inflation. A rule of thumb about when we should expect oscillons is the following:

The potential is quadratic near the origin and "flattens out" for larger values.

An example of such a potential is

$$V(\phi) = \frac{m^2}{2}\phi^2 - \frac{g}{4}\phi^4 + \frac{\lambda}{6}\phi^6 \tag{1}$$

which was studied in detail in [1]. I recommend reading this paper first.

Numerical studies performed in the context of axion monodromy inflation

$$V(\phi) = \mu^3\left(\sqrt{\phi^2+\phi_c^2} - \phi_c\right) \approx \begin{cases} \mu^3\phi & \text{for } \phi \gg \phi_c \\ \frac{\mu^3}{2|\phi_c|}\phi^2 & \text{for } \phi \ll \phi_c \end{cases} \tag{2}$$

also showed copious production of oscillons after inflation [2], as shown in Fig. 2

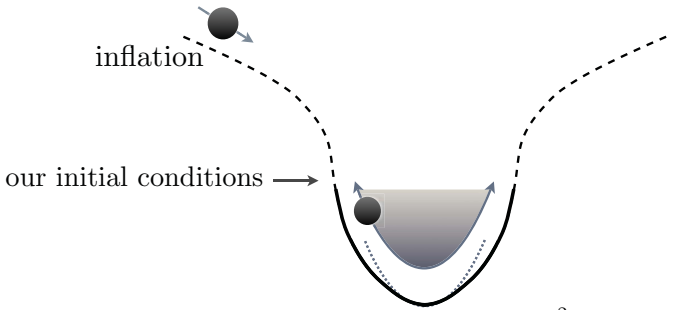

FIG. 1: Pictorial representation of an oscillon potential.

There are many things one can do with regards to oscillons.

- Multi-component oscillons:

  While oscillons have been shown to exist in many models and their properties have been studied using various techniques, 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. I did an analytical study of two-component oscillons [3], but this is the only one I know of. There are numerical studies, like [4], which I would be curious to describe analytically.

- Understand oscillon Dynamics:

  Oscillons are somewhat hard to simulate. In 2 dimensions, a very nice study was performed in [5]. I believe we can understand such behavior using a formalism based on the Non-linear Schrodinger Equation, such as the one used in [3]. This can be the stepping stone into understanding the more realistic 3-dimensional case.

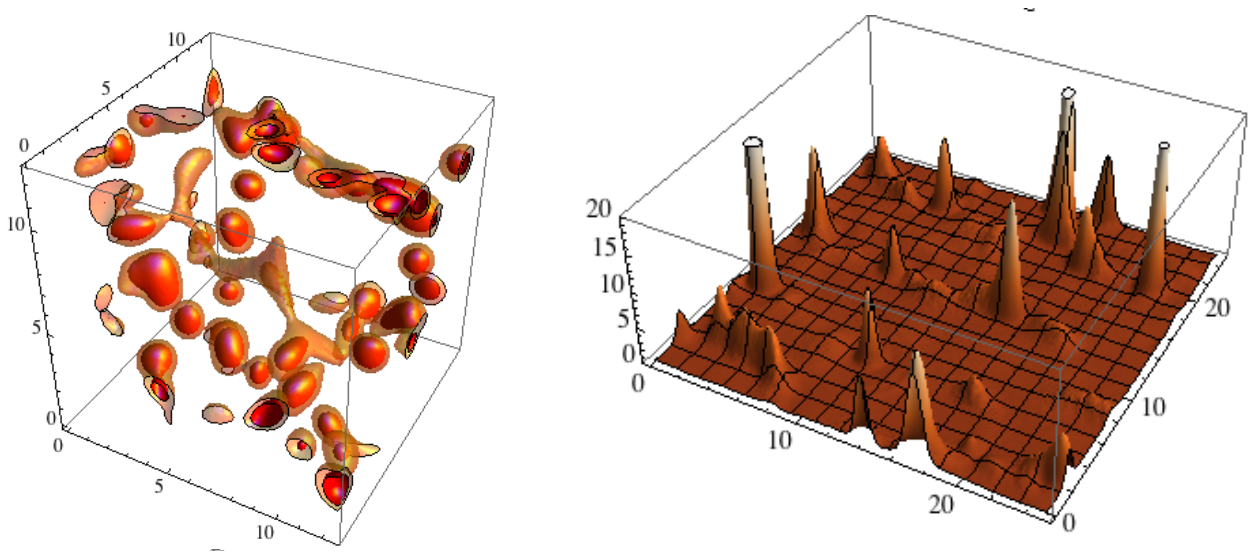

FIG. 2: Numerical simulations of oscillon formation. Left: a 3D box. Right: A 2D slice through the 3D box.

- Explain Gravitational waves from oscillons:

  Gravitational waves from oscillons can arise during their formation or during their subsequent evolution [6, 7], especially if they are non-spherical and can support a long-lived quadrupole moment. I am interested in applying analytical techniques to compute the oscillon quadrupole moment. This can use techniques developed and tested in the project described above "Understand oscillon Dynamics".

---

[1] M. A. Amin and D. Shirokoff, "Flat-top oscillons in an expanding universe," Phys. Rev. D **81**, 085045 (2010) [arXiv:1002.3380 [astro-ph.CO]].

[2] M. A. Amin, R. Easther, H. Finkel, R. Flauger and M. P. Hertzberg, "Oscillons After Inflation," Phys. Rev. Lett. **108**, 241302 (2012) [arXiv:1106.3335 [astro-ph.CO]].

[3] E. I. Sfakianakis, "Analysis of Oscillons in the SU(2) Gauged Higgs Model," arXiv:1210.7568 [hep-ph].

[4] M. Gleiser, N. Graham and N. Stamatopoulos, "Generation of Coherent Structures After Cosmic Inflation," Phys. Rev. D **83**, 096010 (2011) [arXiv:1103.1911 [hep-th]].

[5] M. Hindmarsh and P. Salmi, "Numerical investigations of oscillons in 2 dimensions," Phys. Rev. D **74**, 105005 (2006) [hep-th/0606016].

[6] S. Antusch, F. Cefala and S. Orani, "Gravitational waves from oscillons after inflation," Phys. Rev. Lett. **118**, no. 1, 011303 (2017) [arXiv:1607.01314 [astro-ph.CO]].

[7] J. Liu, Z. K. Guo, R. G. Cai and G. Shiu, "Gravitational Waves from Oscillons with Cuspy Potentials," arXiv:1707.09841 [astro-ph.CO].