Toy models
for Holographic Baryons

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Durham University

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Outline

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- Introduce Topological Solitons

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- Holographic QCD

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- Baby Skyrmions and their variants

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- Examples include sine-Gordon kinks, sigma-model lumps, monopoles, vortices, Skyrmions, Yang-Mills instantons...

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- This leads to a topological charge

$$N = \frac{\phi_+ - \phi_-}{2\pi}$$

where $\phi(x) \to \phi_\pm$ as $x \to \pm\infty$.

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- Saturation of the bound implies a first order equation of motion. In this example we can solve it (for $N = 1$) to find analytic solutions, but this is not always possible.

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- Minimising this over λ gives a scale for the size of the soliton.

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- YM instantons are highly symmetric and there is a wealth of mathematics concerning them!

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- The topological charge is identified with baryon number
- Skyrmions possess interesting symmetries, although their binding energies are too large

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- Formulated in a (4+1) dimensional spacetime with a warped metric of the form

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- The Sakai-Sugimoto takes $p = \frac{2}{3}$ and we say the spacetime is AdS-like

- The Lagrangian is, in suitable units:

$$\mathcal{L} = -\frac{1}{2} Tr(F_{\Gamma\Delta} F^{\Gamma\Delta}) + \frac{9\pi}{\lambda}\omega_5(A_\Gamma)$$

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- Topological solitons in the bulk correspond to Skyrmions on the boundary (coupled to a tower of vector mesons)
- This model is analytically and numerically very complicated

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- Studying a low-dimensional analogue of the SS model makes computations and numerical simulations more feasible
- We can use these toy models to study bulk solitons and test predictions made in the full SS model
- A natural analogue for the Yang-Mills term is an $O(2) - \sigma$ term, since both are scale invariant
- We still have a choice to make regarding the analogue of the Chern-Simons term

Stabilization via the Baby Skyrme Term

- One option is to represent the Chern-Simons term by a baby-Skyrme term

$$\mathcal{L} = \frac{1}{2} g^{\mu\nu} \partial_\mu \boldsymbol{\phi} \cdot \partial_\nu \boldsymbol{\phi} + \frac{\kappa^2}{4} g^{\mu\nu} g^{\alpha\beta} (\partial_\mu \boldsymbol{\phi} \times \partial_\alpha \boldsymbol{\phi}) \cdot (\partial_\nu \boldsymbol{\phi} \times \partial_\beta \boldsymbol{\phi})$$

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- The curvature of spacetime and the baby-Skyrme interaction pick out a preferred size

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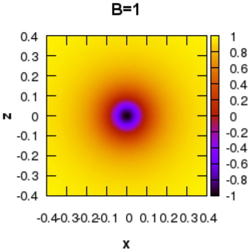

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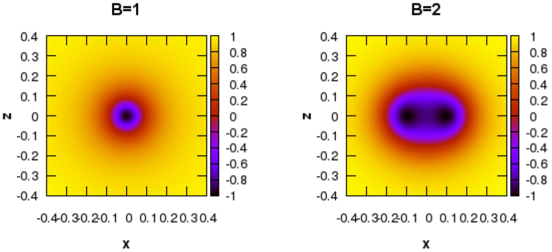

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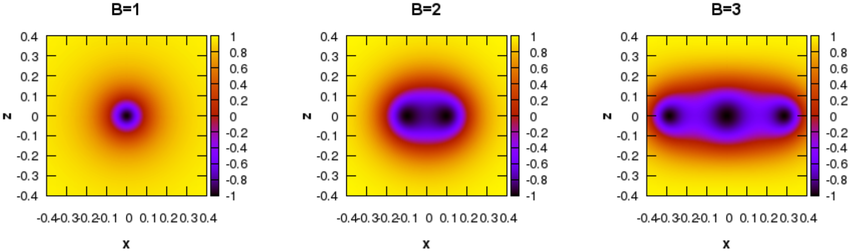

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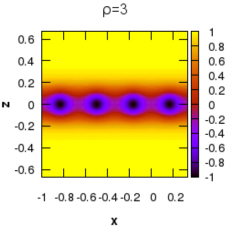

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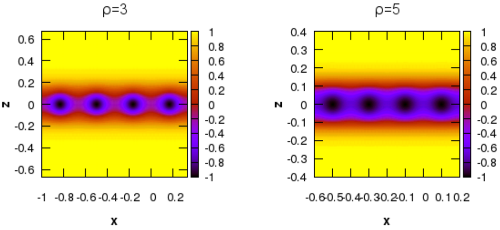

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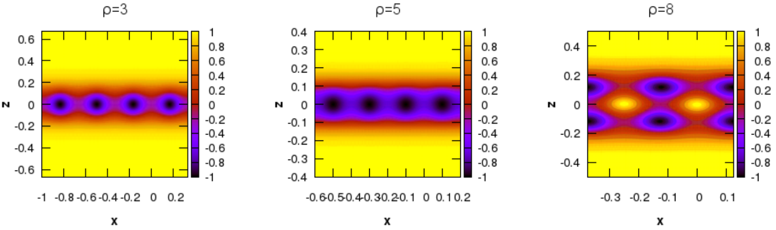

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- It can be shown that the Vector Meson model tends to the Baby Skyrme model in the limit

$$g, M\to\infty\,,\ \frac{g}{M}\propto\kappa\,\text{constant}$$

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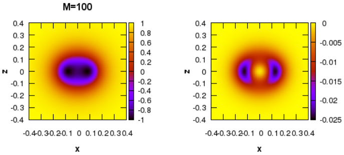

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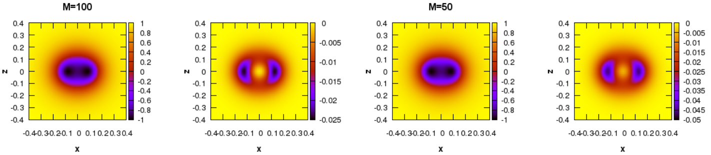

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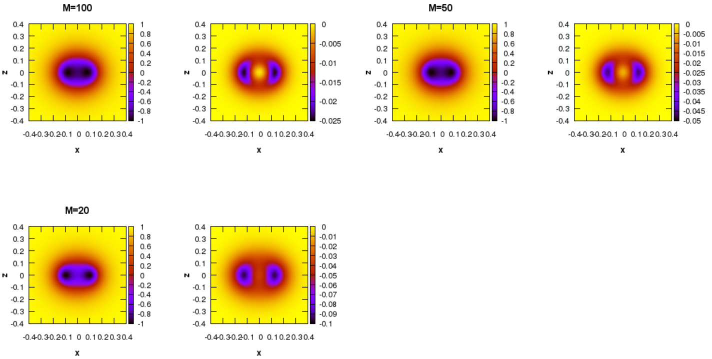

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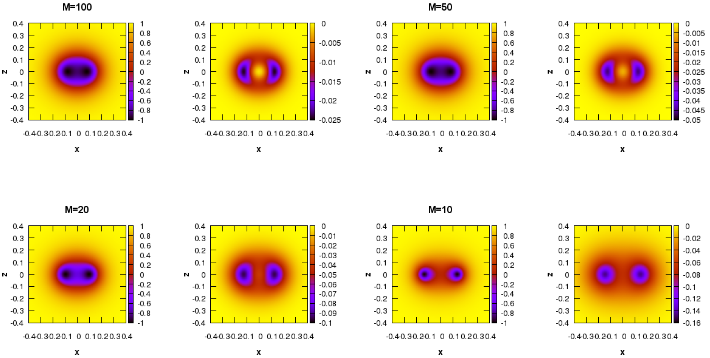

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- Can we find a parameter regime in the Vector Meson model to reproduce this behaviour?

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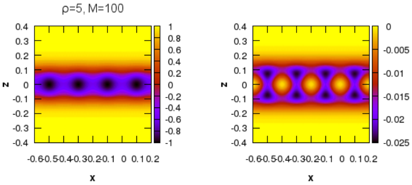

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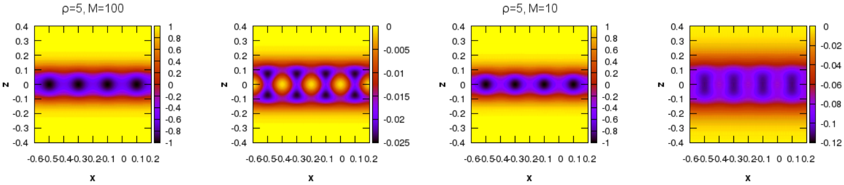
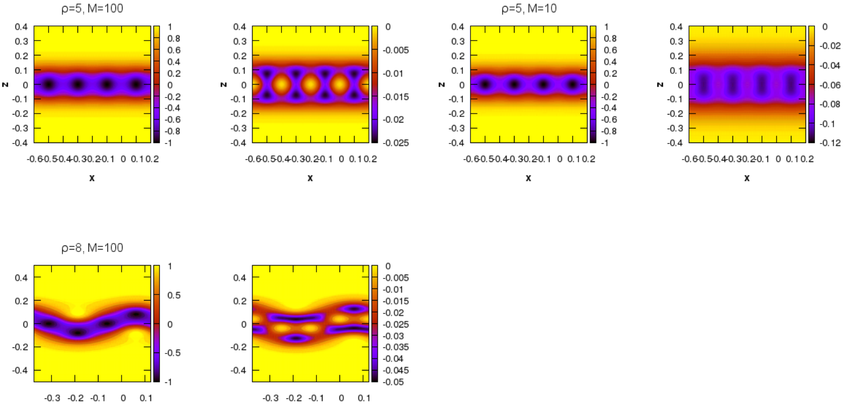
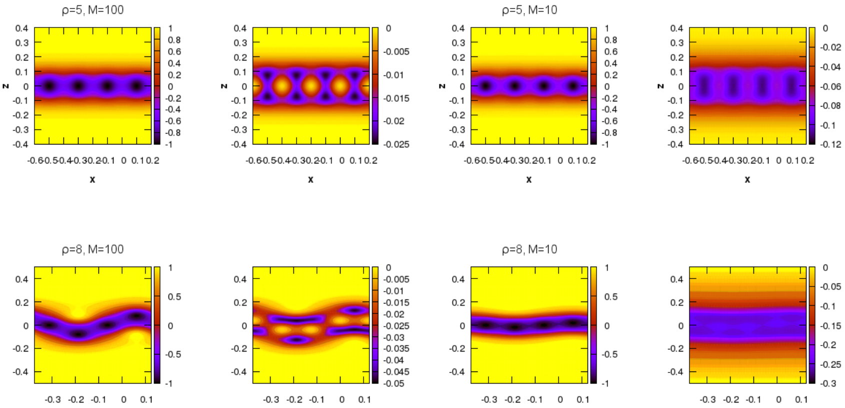


Finite Density Chains



Finite Density Chains



Summary

- Topological solitons have been introduced and many examples have been mentioned
- Introduced the Sakai-Sugimoto model and looked at two lower-dimensional analogues
- Finite density chains of solitons have been investigated in both models
- At lower densities the chains in both models look similar, but at higher densities results are not yet conclusive
- Numerical results require further verification, and analogues of the dyon salt or popcorn phenomena are still to be found in the vector meson model

Thank you for listening.