Equation of state of cold dense matter in compact stars from the gauge-gravity duality

Florian Preis

1 Scientific report for the short term scientific mission

- Project title: Equation of state of cold dense matter in compact stars from the gauge-gravity duality
- Host institution: Southampton Theory, Astrophysics, and Gravity (STAG) research centre
- Host: Andreas Schmitt
- Dates: June 5th to June 12th 2016

2 Purpose of the STSM

It is highly desirable to obtain a single model that is valid for the full density profile of compact stars, incorporating nucleons in a chirally broken phase and quark matter, from which one can obtain an equation of state. Together with my host, Andreas Schmitt, I intend to develop such a model, using the gauge-gravity duality. The purpose of this STSM was to launch the next stage towards this long-term goal and to develop the basis for future collaborations with the group of Nils Andersson situated at the Southampton Theory, Astrophysics, and Gravity (STAG) research centre in order to apply the model to compact stars.

3 Work carried out during the STSM and preliminary results

Shortly before the start of the STSM Andreas Schmitt and I completed an article which builds on recent work by Andreas Schmitt [1], and previous studies of baryonic matter in the Sakai-Sugimoto model [2, 3, 4]. During the STSM we finalized the article for publication in JHEP [5] and assessed the current status of our joint efforts. Indeed, our model is able to describe the vacuum phase, the first order transition to baryonic matter and the expected transition to quark matter within one single approach with five free parameters.

A preliminary analysis of a fit to nuclear properties at saturation proves to be rather restrictive. In particular the fact that the ratio of the onset chemical potential to the baryon mass in vacuum is close to 1, i.e. smallness of the binding energy, restricts the parameter space severely. However, the critical chemical potential of the phase transition to the chirally restored phase turns out to be too large in general. In order to obtain the expected critical potential of 2 to 5 times the critical chemical potential of the baryon onset some fine tuning would be necessary. Nevertheless these fine tuned phase diagrams look promising.

We assigned this deficiency to the lack of fully incorporating the interaction between baryons due to the approximations we made. At the moment we are working on generalizing the calculation for the interaction energy between two baryons (represented by instantons in the gravitational dual theory) to finite density.

4 Future collaboration with the host institution and foreseen publications

The by now well established collaboration with my host will continue and will presumably result in a publication within this year. It will contain a comparison of the currently existing model with the improved version we are working on at the moment as well as the fitting of parameters to saturation properties of nuclear matter and corresponding phase diagrams. The next step would be to calculate the equation of state. Here the collaboration with the group of Nils Andersson started during this STSM will be vital for applying this to the physics of compact stars.

References

[1] Si-wen Li, Andreas Schmitt, and Qun Wang. From holography towards real-world nuclear matter. *Phys. Rev.*, D92(2):026006, 2015.

[2] Oren Bergman, Gilad Lifschytz, and Matthew Lippert. Holographic Nuclear Physics. *JHEP*, 11:056, 2007.

[3] Moshe Rozali, Hsien-Hang Shieh, Mark Van Raamsdonk, and Jackson Wu. Cold Nuclear Matter In Holographic QCD. *JHEP*, 01:053, 2008.

[4] Moshe Rozali, Jared B. Stang, and Mark van Raamsdonk. Holographic Baryons from Oblate Instantons. *JHEP*, 02:044, 2014.

[5] Florian Preis and Andreas Schmitt. Layers of deformed instantons in holographic baryonic matter. *JHEP*, 07:001, 2016.