Numerical study on the Gregory-Laflamme instability of Black Strings by using CCZ4 formulation

Chenxia Gu*
Supervisor: Dr Pau Figueras

School of Mathematical Sciences, Queen Mary University of London

Abstract

Due to the high non-linearity of Einstein equations, numerical relativity is probably the unique way to reveal the nonlinear dynamics of the spacetimes. In our study, we adapt conformal and covariant Z4 (CCZ4) formulation [1] to simulate the spacetime dynamics of the five-dimensional black strings. Previously, the only numerical study on Gregory and Laflamme instability [2] of the five-dimensional black strings was by Lehner and Pretorius, by using the Generalised Harmonic (GH) formulation [3]. They found that the instability develops in a self-similar fashion that with the continuously shrinking of the black string over time, more and more parts of it become hyper-spherical black holes of different sizes. This process will lead to a naked singularity within finite time, which provides an evidence of the violation of the weak cosmic censorship. However, there are lots of questions remain open about the evolution of the horizon and the dynamics of spacetimes in higher dimensions. Hence, the aim of our study is to verify whether the development of horizon follows a self-similar structure and to discover the rules governing it. As a new standard, CCZ4 has the advantages to control the constraint violation and to get rid of excision. In addition, singularity diffusion and modified Gamma-driver are implemented to improve the numerical stability [4, 5]. Modified Cartoon method has been applied to implement symmetry and hence reduce the need of computational resources [6]. The numerical study is carried out by using our own `GRCHOMBO` code [7].

References

[1] D. Alic, C. Bona-Cases, C. Bona, L. Rezzolla, and C. Palenzuela, "Conformal and covariant formulation of the Z4 system with constraint-violation damping," *Phys. Rev.*, vol. D85, no. 064040, 2012.

[2] R. Gregory, "The Gregory-Laflamme instability," vol. 70, no. 2837, 1993.

[3] L. Lehner and F. Pretorius, "Final state of Gregory-Laflamme instability," *Phys. Rev. Lett.*, vol. 105, no. 101102, 2011.

[4] P. Figueras, M. Kunesch, and S. Tunyasuvunakool, "End point of black ring instability and the weak cosmic censorship conjecture," *Phys. Rev. Lett.*, vol. 116, no. 071102, 2016.

[5] P. Figueras, M. Kunesch, L. Lehner, and S. Tunyasuvunakool, "End point of the ultraspinning instability and violation of cosmic conjecture," *Phys. Rev. Lett.*, vol. 118, no. 151103, 2017.

[6] W. G. Cook, P. Figueras, H. Finkel, M. Kunesch, and S. T. Ulrich Sperhake, "Dimensional reduction in numerical relativity: Modified cartoon formalism and regularization," *Int. J. Mod. Phys.*, vol. D25, no. 1641013, 2016.

[7] K. Clough, P. Figueras, H. Finkel, M. Kunesch, E. A. Lim, and S. Tunyasuvunakool, "Gechombo: Numerical relativity with adaptive mesh refinement," *Class. Quant.Grav.*, vol. 32, no. 245011, 2015.

*Email: `chenxia.gu@qmul.ac.uk`