Gravitational waves from long-time evolution of tilted thick disc around a rotating black hole

Alejandro Cruz-Osorio, José Antonio Font and Vassilios Mewes
Departamento de Astronomía y Astrofísica,
Universitat de Valéncia, Dr. Moliner 50, 46100, Valéncia, España.

March 15, 2019

Abstract

The tilted thick disc around a rotating black hole scenario can be formed from BH-NS binary mergers when the BH spin is misaligned with orbital plane of the binary. The numerical relativity simulations from [1] have shown that the Papaloizou-Pringle Instabilities [2] developed during the evolution can produce potentially detectable gravitational waves. In this talk, we will show a 3D numerical relativity simulations of tilted thick torus around a rotating black hole after long-time evolution, around one hundred orbital periods of the disc. We perform this simulation using the public *Einstein Toolkit* [3, 9] code to evolve the Einstein equations written in BSSN formulation [4–6] implemented in *McLachlan* thorn [7,8], while the matter part was evolved using the *GRHydro* thorn [9–11] that solves the general relativistic hydrodynamics equations written in Valencia formulation, using the well known high-resolution shock-capturing methods with Marquina's flux formula and PPM cell reconstructor. The initial data for the thick disc is a self-gravitating solution provided by Stergioulas [11], i. e., satisfy the Einstein equations at $t = 0$. We will present the morphology of the torus and waveform generated from the non-linear dynamics of the tilted disc-black hole system.

References

[1] V. Mewes, J. A. Font, F. Galeazzi, P. J. Montero, N. Stergioulas, "Numerical relativity simulations of thick accretion disks around tilted Kerr black holes" Phys. Rev. D **93** (2016) 064055 doi:10.1103/PhysRevD.93.064055 [SAO/NASA].

[2] J. C. B. Papaloizou J. E. Pringle, "The dynamical stability of differentially rotating discs with constant specific angular momentum" MNRAS **208** 4 721 (1984) [doi:10.1093/mnras/208.4.721].

[3] Einstein Toolkit, "Open software for relativistic astrophysics", [Home].

[4] T. Nakamura, K. Oohara, and Y. Kojima, "General Relativistic Collapse to Black Holes and Gravitational Waves from Black Holes", Prog. Theor. Phys. Suppl. **290**, 1 (1987), [doi:10.1143/PTPS.90.1].

[5] M. Shibata and T. Nakamura, "Evolution of three-dimensional gravitational waves: Harmonic slicing case", Phys. Rev. D **53** (1995) 5428, [doi:10.1103/PhysRevD.52.5428].

[6] T. W. Baumgarte and S. L. Shapiro, "Numerical integration of Einstein's field equations", Phys. Rev. D **59** (024007 (1998), [doi:10.1103/PhysRevD.52.5428].

[7] D. Brown, P. Diener, O. Sarbach, E. Schnetter, and M. Tiglio, "Turduckening black holes: An analytical and computational study", Phys. Rev. D **79** (044023 (2009), [10.1103/PhysRevD.79.044023].

[8] C. Reisswig, C. D. Ott, U. Sperhake, and E. Schnetter, "Gravitational wave extraction in simulations of rotating stellar core collapse", Phys. Rev. D **79** (044023 (2009), [10.1103/PhysRevD.83.064008].

[9] F. Loeffler, J. Faber, E. Bentivegna, T. Bode, P. Diener, R. Haas, I. Hinder, B. C. Mundim, C. D. Ott, E. Schnetter, G. Allen, M. Campanelli, and P. Laguna, "The Einstein Toolkit: a community computational infrastructure for relativistic astrophysics", Classical Quantum Gravity **29**, 115001 (2012), [10.1088/0264-9381/29/11/115001].

[10] L. Baiotti, I. Hawke, P. J. Montero, F. Loeffler, L. Rezzolla, N. Stergioulas, J. A. Font, and E. Seidel, "Three-dimensional relativistic simulations of rotating neutron-star collapse to a Kerr black hole", Phys. Rev. D **71** 024035 (2005), [10.1103/PhysRevD.71.024035].

[11] P. Moesta, B. C. Mundim, J. A. Faber, R. Haas, S. C. Noble, T. Bode, F. Loeffler, C.D. Ott, C. Reisswig, and E. Schnetter, "GRHydro: a new open-source general-relativistic magnetohydrodynamics code for the Einstein toolkit", Classical Quantum Gravity **31**, 015005 (2014), [10.1088/0264-9381/31/1/015005].

[11] N. Stergioulas, "Black hole spacetimes with self-gravitating, massive accretion tori", J. Phys. Conf. Ser. **283**, 012036 (2011), [10.1088/1742-6596/283/1/012036].