Robinson–Trautman solutions in (2+1) dimensions

Alberto Saa
Departmento de Matemática Aplicada, Universidade Estadual de Campinas,
13083-859 Campinas, SP, Brazil. E-mail: asaa@ime.unicamp.br

The Robinson-Trautman (RT) spacetime [1] is perhaps the simplest solution of General Relativity describing a compact source surrounded by gravitational waves. As an initial value problem, the RT spacetime evolution is a well-posed problem, in the sense that a regular initial data will evolve smoothly according to the RT equations towards a final state corresponding to a remnant Schwarzschild black-hole [2]. The RT equations have an interesting geometrical interpretation, they indeed correspond to a two-dimensional Calabi flow, an they can provide several physically interesting pictures as, for instance, for the problem of gravitational wave recoil [3]. Extensions of RT spacetimes for higher dimensions ($D > 4$) were considered in detail in [4]. Despite some differences in the algebraic classification of the corresponding Weyl tensors, the essence of the RT evolution is unchanged: regular initial data evolve towards a final higher-dimensional Schwarzschild black-hole.

Curiously, the situation for $(2+1)$ dimensions is quite different. Since the Riemann tensor is completely determined by its traces (namely the Ricci tensor and the scalar curvature), any Ricci flat solution will be necessarily flat, implying the absence of standard gravitational waves for GR in $D = 3$. Such a behavior is essentially the same in the presence of a cosmological constant. However, since there indeed exists a physically consistent black-hole solution for GR in $D = 3$ with a negative cosmological constant, namely the so-called BTZ black-hole [5], it would be interesting to have a $(2+1)$ RT solution mimicking the higher dimensional initial value problems. That is precisely the problem considered here. The vacuum solutions of GR in $(2+1)$ dimensions, including the cases with a cosmological constant, were considered recently in [6], from where we import all conventions and notations. We propose a $(2+1)$ RT flow mimicking all the essential properties of the Calabi flow in $D = 4$ GR. In particular, regular initial data evolve towards a final remnant BTZ, and any possible asymmetry in the initial data is expelled as a radiation fluid. Further details on the proposed $(2+1)$ RT flow and its physical interpretation can be found in [7].

References

[1] H. Stephani, D. Kramer, M. MacCallum, C. Hoenselaers, E. Herlt, *Exact Solutions of Einstein's Field Equations*, 2nd Edition, Cambridge University Press, 2002.
[2] P. Chrusciel, Comm. Math. Phys. **137**, 289 (1991).
[3] R.P. Macedo and A. Saa, Phys. Rev. D**78**, 104025 (2008). [arXiv:0809.3039]
[4] J. Podolsky and M. Ortaggio, Class. Quantum Grav. **23**, 5785 (2006). [arXiv:gr-qc/0605136]
[5] M. Banados, C. Teitelboim, J. Zanelli, Phys. Rev. Lett. **69**, 1849 (1992). [arXiv:hep-th/9204099]
[6] J. Podolsky, R. Svarc, H. Maeda, Class. Quantum Grav. **36**, 015009 (2019). [arXiv:1809.02480]
[7] http://vigo.ime.unicamp.br/RT3