Black hole equations of motion in the null gauge with back reaction due to radiation

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The strategy to build equations of motion by requiring to balance the amount of momentum radiated has proved to be useful in the context of charged particles; since in reference [1] we have presented a new derivation of the equations of motion of charged particles which generalizes the very well know Lorentz-Dirac equations of motion.

The extension of this idea to relativistic theories of gravity is much more involved; since it must deal with a series of technical difficulties that should be handled. For instance, when considering an isolated compact object, it induces one to represent it by an asymptotically flat spacetime. In the asymptotic region one can always write the metric as

$$g = \eta_{\rm asy} + h_{\rm asy}; \tag{1}$$

where $\eta_{\rm asy}$ is a flat metric associated to inertial frames in the asymptotic region and $h_{\rm asy}$ the tensor where all the physical information is encoded. But there are as many flat metrics $\eta_{\rm asy}$ as there are BMS proper supertranslation generators. We have explained in [2] the difficulties in finding appropriate rest frames, and how to solve these issues; making use of supertranslation free definition of intrinsic angular momentum[3, 4]. The root of all obstacles is the appearance of gravitational radiation. Because of this when studying the dynamics of compact objects we take into account the back reaction due to gravitational radiation as our starting point.

In [2] we have presented the formal aspects and the problems that could arise in a model for a compact object, treated as a particle on an appropriately chosen flat background. The idea one has in mind is to apply this construction to a binary system, so that each of the compact objects will be treated likewise. The flat background metric by construction will share the same asymptotic region as the full metric of the spacetime: so that one of the inertial systems at infinity would be related to this flat global metric.

We here develop further the general framework for modeling the dynamics of the motion of black holes, presented in [2], by employing a convenient null gauge, in general relativity, for the construction of the balanced equations of motion. This null gauge has the property that the asymptotic structure is intimately related to the interior one; in particular there is a strong connexion between the field equation and the balanced equations of motion.

Our work is very related to what we have called 'Robinson-Trautman(RT) geometries' in the past. These geometries are used in the sense of the general framework we have presented in [2].

We will present the balanced equations of motion in second order of the acceleration; which in the appropriate frame it can be expressed as

$$\mathbf{a}^\mu = \mathbf{f}^\mu + \dot{\left(\alpha M \mathbf{f}^\nu\right)} + \beta M \mathbf{f}^\nu \mathbf{f}_\nu \mathbf{v}^\mu + f^\mu_\lambda; \tag{2}$$

where $\dot{\left(\alpha M \mathbf{f}^\nu\right)}$ denotes the time derivative of $\left(\alpha M \mathbf{f}^\nu\right)$, $\mathbf{f}^\mu$ represents the contribution to the acceleration due to the other body, α and β are new degrees of freedom, and f^μ_λ is the radiated momentum per unit mass.

We will show how to solve the required components of the field equation at their respective required orders, G^2 and G^3, in terms of the gravitational constant.

We will indicate how this approach can be extended to higher orders.

References

[1] E. Gallo and O. M. Moreschi, "New derivation for the equations of motion for particles in electromagnetism," *Phys.Rev.* **D85** (2012) 065005, `arXiv:1112.5344 [gr-qc]`.

[2] E. Gallo and O. M. Moreschi, "Modeling the dynamics of black holes through balanced equations of motion," *IJGMMP* (2019) . article number 1950034.

[3] O. M. Moreschi, "Intrinsic angular momentum and center of mass in general relativity," *Class.Quantum Grav.* **21** (2004) 5409–5425.

[4] E. Gallo and O. M. Moreschi, "Intrinsic angular momentum for radiating spacetimes which agrees with the Komar integral in the axisymmetric case," *Phys.Rev.* **D89** (2014) 084009, `arXiv:1404.2475 [gr-qc]`.