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BOOK REVIEW

Equation of Motion in General Relativity, by Hideki Asada, Toshifumi Futamase and Peter A. Hogan, Oxford University Press, Oxford 2011, x + 153 pages, ISBN-978-0-19958-410-9.

The book offers an almost complete guide for the study of the motion of extended bodies and the motion of small black holes in external gravitational and electromagnetic fields. The equations of motion are derived in the post Newtonian approximation in which the strong internal gravity of bodies is taken into account. For small black holes the equations of motion are derived from Einstein field equations requiring that the wave fronts of the produced radiation are smoothly deformed spheres near the black hole. Advance of periastron, light deflection, Shapiro time delay, orbital period decay and spin precession are described in detail and the book ends with a discussion of few-body system both in Newtonian and Einstein gravity.

The book architecture consists of an Introduction, six chapters and four Appendices.

In the *Introduction*, the readers are provided with an historical description of the field, supported by a detailed list of references ranging from the seminal paper by Einstein, Infeld and Hoffmann (1938) to the most recent results stressing their relevance for the ongoing interferometric gravitational wave experiments. The authors also discuss the approach chosen to present the equation of motion of small black holes.

The first three chapters concern the motion of extended bodies in General Relativity.

The chapter *Foundation of the Post-Newtonian Approximation* is devoted to an introduction of the basic notion presented in the book. Starting from a general definition of asymptotic approximation of a theory, the authors define the Newtonian, Post-Newtonian and higher approximation of various quantities. A concrete example in harmonic coordinates is presented. The strong field point particle limit, the surface integral approach to the evaluation of the equations of motion are then presented and the scaling of the initial data is discussed. The Newtonian equations of

motion for extended bodies and the first post-Newtonian approximation are derived and the near zone and body zone contributions are discussed.

In the third chapter *Third Post-Newtonian Approximation*, the equations of motion, the 3PN mass-energy relation and 3PN momentum-velocity relation are derived. The arising of logarithmic terms depending on arbitrary parameters is discussed. Eventually some observations and comments on alternative approaches are given.

In the chapter *Two-body Problem in General Relativity*, the physical properties of a binary star system are discussed. The equations describing periastron advance, light deflection, Shapiro time delay, orbital period decay due to gravitational radiation emission and spin precession are derived.

The following two chapters are devoted to small black holes and their motion in an external gravitational field.

In the fifth chapter *Small Black Holes*: *Geometrical Preliminaries*, the background considered space-time is expressed using the Fermi property, while the world-line of the small black hole is a time-like geodesic. A suitable parametrization of the background line-element is then introduced. Eventually, the field equations near the world-line are considered in the case of Einstein-Maxwell vacuum background.

In the next chapter *Small Charged Black Holes*: *Equations of Motion*, the afore mentioned problem is generalized to a charged black hole introduced as a perturbation of the background Einstein-Maxwell space-time formerly described.

In the last chapter, *Gravitational Physics of Few-Body Systems*, starting from a brief historical introduction to the classical three-body problem in Newtonian gravity, figure-eight solutions are discussed both in Newtonian theory and in General Relativity. Some specific examples are presented and the relevance of these particular solutions, in connection with gravitational waves physics, is discussed.

The first two appendices contain calculations relevant for the second chapter. In *Appendix A*, the far zone contribution to the retardation expansion (up to the 3rd post-newtonian order) is discussed. In *Appendix B* the spin-orbit, the quadrupole-orbit, spin-spin coupling forces and the spin geodesic precession equation at lowest order are derived.

In *Appendix C*, null geodesic congruences are discussed in the null tetrad formalism and a physical/geometric interpretation of expansion, shear and twist scalars is provided.

In *Appendix D*, the leading terms and tolerated errors for the perturbative expansion of chapter 6 are presented.

The study of motion of extended bodies in General Relativity is a highly technical job which is notorious for its analytical difficulty. It is, however, highly relevant for

it allows to compare predictions of the theory and results from modern measurements both in relativistic astrophysics and cosmology. The book fills a long time gap in the existing literature on the subject and includes a complete bibliography with commentary. It will be a useful reference for all researchers interested in the predictions of Einstein's general relativity theory.

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