Numerical versus analytical accuracy of the formulas for light propagation

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Numerical integration of the differential equations of light propagation in the Schwarzschild metric shows that in some situations relevant for practical observations the well-known post-Newtonian solution for light propagation has an error up to 16 microarcsecond. The aim of this work is to demonstrate this fact, identify the reason for this error and to derive an analytical formula accurate at the level of 1 microarcsecond as needed for high-accuracy astrometric projects (e.g., Gaia).
An analytical post-post-Newtonian solution for the light propagation for both Cauchy and boundary problems is given for the Schwarzschild metric augmented by the PPN and post-linear parameters β, γ and ϵ. Using analytical upper estimates of each term we investigate which post-post-Newtonian terms may play a role for an observer in the solar system at the level of 1 microarcsecond and conclude that only one post-post-Newtonian term remains important for this numerical accuracy. In this way, an analytical solution for the bounda problem for light propagation is derived. That solution contains terms of both post-Newtonian and post-post-Newtonian order, but is valid for the given numerical level of 1 microarcsecond. Th derived analytical solution has been verified using the results of a high-accuracy numerical integration of differential equations of light propagation and found to be correct at the level well below 1 microarcsecond for arbitrary observer situated within the solar system. Furthermore, the origin of the post-post-Newtonian terms relevant for the microarcsecond accuracy is elucidat We demonstrate that these terms result from an inadequate choice of the impact parameter in the standard post-Newtonian formulas.

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