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Revisiting compaction functions for primordial black hole formation

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Shibata and Sasaki [Phys. Rev. D 60, 084002 (1999)] introduced the so-called compaction function. Since then, it has been empirically established that the maximum value of this function (or its volume-averaged counterpart) in the long-wavelength solutions gives a very robust threshold of primordial black hole formation. In this paper, we show that in spite of initial intention, the Shibata-Sasaki compaction function cannot be interpreted as the ratio of the mass excess to the areal radius in the constant-mean-curvature slice of their choice but coincides with that in the comoving slice up to a constant factor depending on the equation of state. We also discuss the gauge (in)dependence of the legitimate compaction function, i.e., the ratio of the mass excess to the areal radius, in the long-wavelength solutions.

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