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Primordial black hole formation from a nonspherical density profile with a misaligned deformation tensor

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We perform the numerical simulation of primordial black hole formation from a nonspherical profile of the initial curvature perturbation ζ. We consider the background expanding universe filled with the perfect fluid with the linear equation of state $p = w\rho$ ($w = 1/3$ or $1/5$), where p and ρ are the pressure and the energy density, respectively. The initial condition is set in a way such that the principal directions of the second derivatives of ζ and $\triangle\zeta$ at the central peak are misaligned, where $\triangle$ is the Laplacian. In this setting, since the linearized density is proportional to $\triangle\zeta$, the inertia tensor and deformation tensor $\partial_i\partial_j\zeta$ are misaligned. Thus tidal torque may act and the spin of a resultant primordial black hole would be non-zero in general, although it is estimated to be very small from previous perturbative analyses. As a result, we do not find a finite value of the spin within our numerical precision, giving support for the negligibly small value of the black hole spin for $1/5$
$lesssim w$
$lesssim 1/3$. More specifically, our results suggest that the dimensionless PBH spin s is typically so small that $s \ll 0.1$ for w
$gtrsim 0.2$.

Primary author: YOO, Chulmoon (Nagoya Univ.)

Presenter: YOO, Chulmoon (Nagoya Univ.)

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