Contribution ID: **61** Type: **not specified**

Primordial black hole formation from a massless scalar field

Thursday, 20 June 2024 09:50 (20 minutes)

We consider primordial black holes formation from adiabatic cosmological perturbation of the Early Universe dominated by a massless scalar field. These are sourced by a time independent curvature profile imposed on super horizon scale, corresponding to pure growing modes of the scalar field. Assuming spherical symmetry we study the collapse of these cosmological perturbations using the comoving and the constant mean curvature gauge, showing that the behaviour of a massless scalar field is equivalent to a perfect fluid where the pressure is equal to the total energy density (i.e. equation of state $p = \rho$). Using a numerical code based on the BSSN conformal decomposition, developed specifically for this problem, we computed the threshold δ_c, defined as the peak of the compaction function $\mathcal{C}(r)$ measured on super horizon scales. This is equivalent to the relative mass excess measured at the cosmological horizon crossing.

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Session Classification: Session 13