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Charting the Landscape in Our Neighborhood from the PBHs Mass Distribution and GWs

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We explicitly construct a double field inflationary model, which satisfies the latest PLANCK constraints at the CMB scales and produces the whole dark matter energy density as primordial black holes (PBHs), in the mass range 10^{-17}~M_{\odot}\lesssim M_{{}*{\rm PBH}}\lesssim 10^{-13}~M*{\odot}. The PBHs can be produced after the end of slow-roll inflation from the bubbles of true vacuum that nucleate during the course of inflation. Obtaining PBHs in this mass range enforces the scale of inflation to be extremely low, 10^{-7}~{\rm GeV}\lesssim H \lesssim 10^{-3} ~{\rm GeV}, which makes the efforts to observe gravitational waves at the CMB scales futile, although it is high enough to allow for a successful Big Bang Nucleosynthesis (BBN). We will show that the shape of the mass distribution of the PBHs is dependent on how inflation ends and the universe settles from the metastable direction to the true one. In particular, if settling to the true vacuum occurs with a first-order phase transition (PT) happens a bit after the termination of inflation by the slow-roll violation, the subcritical bubbles find enough time to collapse to PBHs, and the first order PT leaves behind a stochastic gravitational wave background (SGWB), which is {\it potentially} observable by LISA. On the other hand, if exit from inflation and settling to the true vacuum both occur with a first order PT, all the bubbles collide before they find the chance to collapse to PBHs, but an SGWB typical of first order PT will be left as a signature. In the other extreme scenario, if exit from the false valley to the true one occurs through a second order instability, there will be only PBHs in both sub- and supercritical branches of the mass distribution, but there will be no SGWB typical of first order PT. We also show that PBHs produced during such a first-order PT from the collision of bubble walls contribute negligibly to the PBH mass spectrum. Examining the mass distribution of PBHs and possible SGWB from the end of inflation, we may be able to gain invaluable information about the topography of the landscape in our neighborhood.

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