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The observed number counts in luminosity distance space

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Next generation surveys will provide us with an unprecedented number of detections of supernovae Type Ia and gravitational wave merger events. Cross-correlations of such objects offer novel and powerful insights into the large-scale distribution of matter in the universe. Both of these sources carry information on their luminosity distance, but remain uninformative about their redshifts; hence their clustering analyses and cross-correlations need to be carried out in luminosity distance space, as opposed to redshift space. In this paper, we calculate the full expression for the number count fluctuation in terms of a perturbation to the observed luminosity distance. We find the expression to differ significantly from the one commonly used in redshift space. Furthermore, we present a comparison of the number count angular power spectra between luminosity distance and redshift spaces. We see a wide divergence between the two at large scales, and we note that lensing is the main contribution to such differences. On such scales and at higher redshifts the difference between the angular power spectra in luminosity distance and redshift spaces can be roughly 50%. We also investigate cross-correlating different redshift bins using different tracers, i.e. one in luminosity distance space and one in redshift, simulating the cross-correlation angular power spectrum between background gravitational waves/supernovae and foreground galaxies. Finally, we show that in a cosmic variance limited survey, the relativistic corrections to the density-only term ought to be included.

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