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Dispersion in the Hubble-Lemaitre constant measurements from gravitational clustering

Measurements of the Hubble-Lemaitre constant H_0 require us to estimate the distance and recession velocity of galaxies independently. Gravitational clustering that leads to the formation of galaxies and the large scale structure leaves its imprints in the form of peculiar velocities of galaxies. In general, it is not possible to disentangle the peculiar velocity component from the recession velocities of galaxies, and this introduces an uncertainty in the determination of H_0. We use cosmological N-body simulations to quantify the impact of peculiar velocities on the estimation of H_0. We consider observers to be located in dark matter halos and target galaxies to be distributed amongst dark matter halos. We compute the distribution of the estimated value of H_0 across all such observers in the simulation, and we study the distribution as a function of distance from the observer. We find that the dispersion of this distribution is large at small scales, and it diminishes as we go to large separations, reaching the level of the quoted statistical error in Planck and SH0ES measurements well beyond 135 Mpc and 220 Mpc respectively. Measurements at smaller scales are susceptible to errors arising from peculiar motions and this error can propagate to measurements at larger scales in the distance ladder. Notably, we observe a weak negative correlation between the local over-density around an observer and the deviation of the local and the global value of H_0. We show that deviations more significant than 5% of the global values can be encountered frequently at scales of up to 40 Mpc, and this is considerably larger than the statistical errors on local estimates.

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