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Pairwise Velocities of Dark Matter Halos: a Test for the Lambda Cold Dark Matter Model using the Bullet Cluster

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The existence of 1E0657-56 poses a challenge to the concordance Lambda cold dark matter model. Here we investigate the velocity distribution of dark matter halo pairs in large N-body simulations with differing box sizes (250Mpc/h-2 Gpc/h) and resolutions. We examine statistics such as the halo masses, pairwise halo velocities (v_{12}), and pair separation distances. We then compare our results to the initial conditions (ICs) required to reproduce the observational properties of 1E0657-56 in non-cosmological hydrodynamical simulations. We find that the high velocity tail of the v_{12} distribution extends to greater velocities as we increase the box size. We also find that the number of high-v_{12} pairs increases as we increase the particle count and resolution with a fixed box size, however, this increase is mostly due to lower mass halos which do not match the observed masses of 1E0657-56. We find that the redshift evolution is not very strong for the v_{12} distribution function between z=0.0 and z~0.5. We identify some pairs whose v_{12} resemble the required ICs, however, even the best candidates have either wrong halo mass ratios, or too large separations. Our simulations suggest that it is very difficult to produce such ICs at z=0.0, 0.296,& 0.489 in comoving volumes as large as (2Gpc/h)^3. Based on the extrapolation of our cumulative v_{12} function, we find that one needs a simulation with a comoving box size of (4.48Gpc/h)^3 and 2240^3 DM particles in order to produce at least one pair of halos that resembles the required v_{12} and observed masses of 1E0657-56. We find that the probability of finding a halo pair with v_{12}>=3000km/s and masses >=10^{14}Msun to be 2.76x10^{-8} at z=0.489. We conclude that either 1E0657-56 is incompatible with the concordance LCDM universe, or the ICs suggested by the non-cosmological simulations must be revised to give a lower value of v_{12}.

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