U17a Modification of distance-redshift relation in a clumpy universe

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Propagation of light in a clumpy universe is examined. As an inhomogeneous matter distribution, we take a spherical void surrounded by a dust-shell where the "lost mass" in the void is compensated by the shell. We study how the angular-diameter distance behaves when such a structure exists.

The angular-diameter distance is defined in terms of the expansion, using the geometric optics. Then the angular-diameter distance is calculated as a function of the affine parameter of the null geodesic, by integrating the Raychaudhuri equation including the shear. At the shell, we give a condition for the jump of the shear and the expansion, while the distance is continuous. An explicit expression for the junction condition at the massive thin shell is calculated in terms of the null vector of the light, 4-velocity of the shell, and the energy momentum tensor of the shell. We apply these results to a dust shell embedded in a Friedmann universe, and see how the distance-redshift relation is modified compared that in the purely Friedmann universe. Its cosmological implication is also discussed.