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Redshift and distances in a ΛCDM cosmology with non-linear inhomogeneities

Nikolai Meures, Marco Bruni (ICG, Portsmouth)

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Motivated by the dawn of precision cosmology and the wealth of forthcoming high precision and volume galaxy surveys, in this paper we study the effects of inhomogeneities on light propagation in a flat \Lambda CDM background. To this end we use exact solutions of Einstein's equations (Meures & Bruni 2011) where, starting from small fluctuations, inhomogeneities arise from a standard growing mode and become non-linear. While the matter distribution in these models is necessarily idealised, there is still enough freedom to assume an arbitrary initial density profile along the line of sight. We can therefore model over-densities and voids of various sizes and distributions, e.g. single harmonic sinusoidal modes, coupled modes, and more general distributions in a \Lambda CDM background. Our models allow for an exact treatment of the light propagation problem, so that the results are unaffected by approximations and unambiguous. Along lines of sight with density inhomogeneities which average out on scales less than the Hubble radius, we find the distance redshift relation to diverge negligibly from the Friedmann-Lemaitre-Robertson-Walker (FLRW) result. On the contrary, if we observe along lines of sight which do not have the same average density as the background, we find large deviations from the FLRW distance redshift relation. Hence, a possibly large systematic might be introduced into the analysis of cosmological observations, e.g. supernovae, if we observe along lines of sight which are typically more or less dense than the average density of the Universe. In turn, this could lead to wrong parameter estimation: even if the Cosmological Principle is valid, the identification of the true FLRW background in an inhomogeneous universe maybe more difficult than usually assumed.

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