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Dipoles and structures in cosmological numerical relativity simulations

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We apply fully general relativistic (GR) ray-tracing to large cosmological simulations. The simulations of Macpherson et al. integrate the full Einstein equations from initial conditions at the cosmic microwave background (CMB) to the present epoch. These simulations reproduce a realistic cosmic web from the initial matter power spectrum, which is already well studied.

For the first time, we study how light from isotropic sources at large distances out to redshift $z = 3$ is affected by intervening structure in GR simulations. An ensemble of simulated observers in the fluid rest frame, at various locations in the cosmic web, all measure a dipole in the observed photon energies. The magnitude of each of these simulated dipoles is comparable to the magnitude of our observed CMB dipole. However, this dipole does not disappear in the simulation rest frame —which should be close to FLRW. Thus it cannot be associated with the observer's peculiar velocity.

The principal contributions to this dipole are from structures at redshifts $z < 0.1$, those nearby each observer contributing the most. When these structures are cut, isotropy is restored.

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