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## Bispectrum correlations of HI intensity mapping and large-scale structure surveys

Neutral hydrogen (HI) intensity mapping (IM) experiments probe the large-scale structure of the universe through the integrated redshifted 21-cm line emission from unresolved sources of neutral hydrogen. Optical surveys also probe the large-scale structure of the universe with much higher precision and depth by mapping the galaxy distribution. In this article, we study the cross-correlations of the HI IM field from HIRAX (Hydrogen Intensity and Real-time Analysis eXperiment) with the galaxy density and cosmic shear fields from the Rubin observatory large-scale structure survey, laying down the tools to do parameter forecasts and study constraints on the neutral hydrogen fraction, galaxy bias, and cosmological parameters. Astrophysical foregrounds limit the long-wavelength line-of-sight HI modes, reducing the constraining power of these cross-correlations. We introduce bispectrum estimators, specifically HI-HI-galaxy density and HI-HI-shear cross bispectra estimators, to recover modes lost in the foreground subtraction process and improve the parameter constraints.

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