Detection of Kinematic Dipolar Modulation in Large-Scale Structure

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- Expected Kinematic dipolar modulation in LSS

\[ A = 2 \tilde{\beta} = 2 \beta [1 + 1.25x(1 - p)] \]

Itoh et al. (2010)

- Relativistic aberration (2\(\beta\)):
The galaxies along the direction of our motion look bunched up due to the relativistic effect.

- Doppler effect

The number of observed galaxies within the limited bandwidth changes due to Doppler effect.

Measuring dipolar modulation in LSS can be a good test for standard cosmology.
Statistical Error and Systematic Bias

• Statistical Error (Fisher matrix analysis):

\[ \hat{x} = F^{-1} g \]
\[ g_i = \int T_i(\hat{n}) \delta N^\Omega(\hat{n}) d^2\hat{n} \]
\[ F_{ij} = \tilde{N}^\Omega \int T_i(\hat{n}) T_j(\hat{n}) d^2\hat{n} \]
\[ T(\hat{n}) = (n_x, n_y, n_z, t_1, t_2, \ldots, t_N, 1) \]

\[ \sigma(A) = \sqrt{[ (F_{mar}^{3\times3})^{-1} ]_{AA}} \]

✓ Considered survey coverage, survey shapes and number of objects.

• Systematic Bias:

\[ d_{obs} = d_{kin} + d_{local} \]

\[ \Delta \chi^2(d_{local}) = \text{systematic bias}^2 / \text{statistical error}^2 \]

✓ We treat the contribution from the local structure dipole as a systematic bias on the detection of kinematic dipole. The amplitude of the local structure dipole decreases in a deeper region.
Can we detect it in the future?

- 4 different simplified footprints were tested.
- 3-σ and 5-σ detections are easily achievable with ±15 deg galactic cut and 9M, 30M objects, respectively at the depth of the survey $z_{\text{med}} \sim 0.75$.
- A survey such as SPHEREx is ideal for dipole detection due to wide coverage and sufficient number of objects.
- Combined data will increase possibility of dipole detection. e.g. Combining a previous survey, WISE (photometric) data with DESI (spectroscopic) will enable WISE to identify and utilize more galaxies at deeper depth.