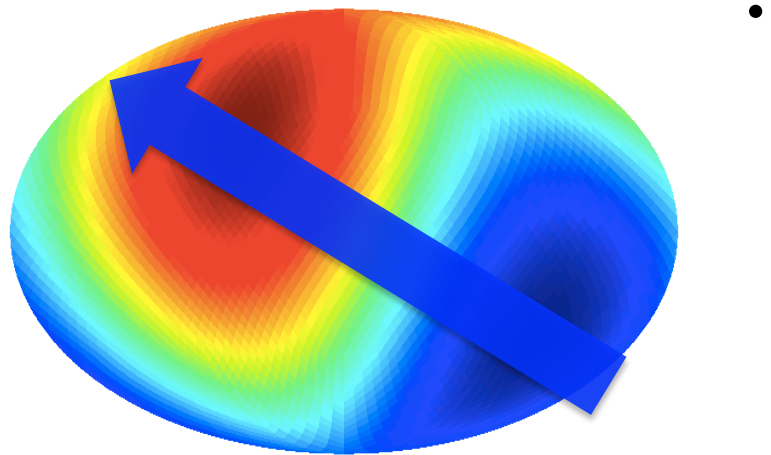


# Detection of Kinematic Dipolar Modulation in Large-Scale Structure

Mijin Yoon, and Dragan Huterer

<https://arxiv.org/1509.05374>, ApJ 813 (2015) L18



$$N(\hat{\mathbf{n}}) = [1 + A(\hat{\mathbf{d}} \cdot \hat{\mathbf{n}})]\bar{N} + \varepsilon(\hat{\mathbf{n}})$$

↖ Dipole direction  
↖ Dipole amplitude

- 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 ( $[1 + 1.25x(1 - p)]$ ):

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):

$$\hat{x} = F^{-1}g$$

$$g_i = \int T_i(\hat{n}) \delta N^\Omega(\hat{n}) d^2 \hat{n}$$

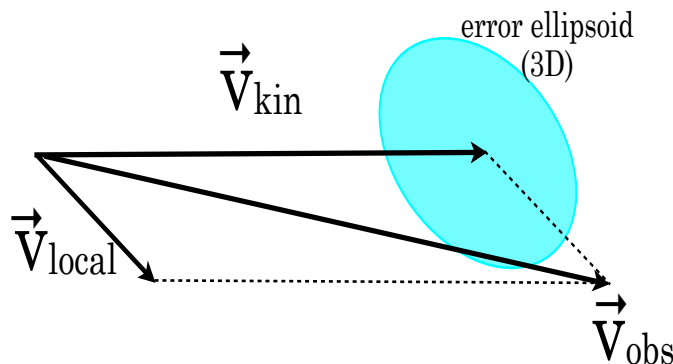
$$F_{ij} = \bar{N}^\Omega \int T_i(\hat{n}) T_j(\hat{n}) d^2 \hat{n}$$

$$T(\hat{n}) = (n_x, n_y, n_z, t_1, t_2, \dots, t_N, 1)$$

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

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

- Systematic Bias:

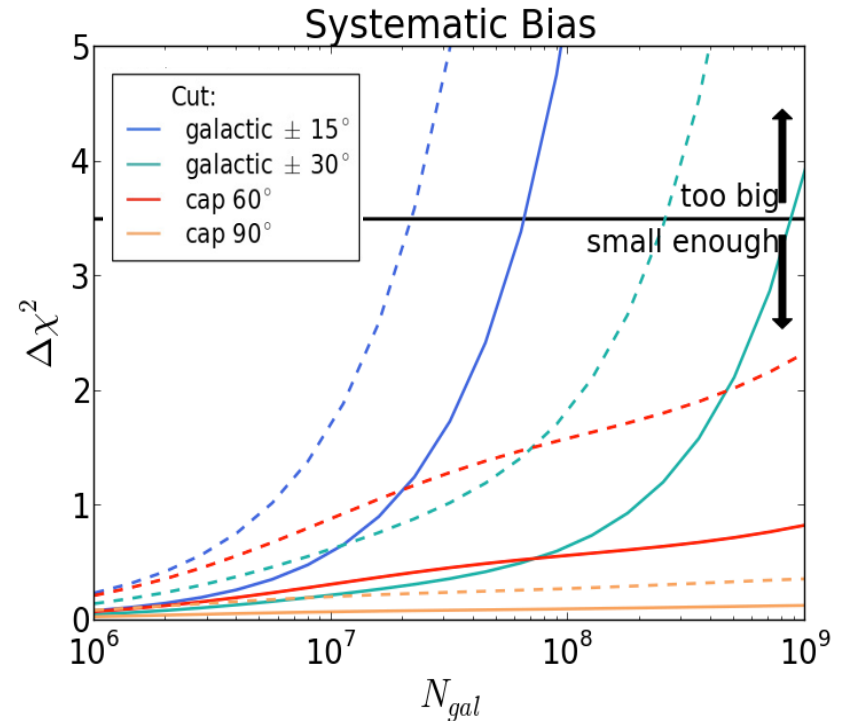
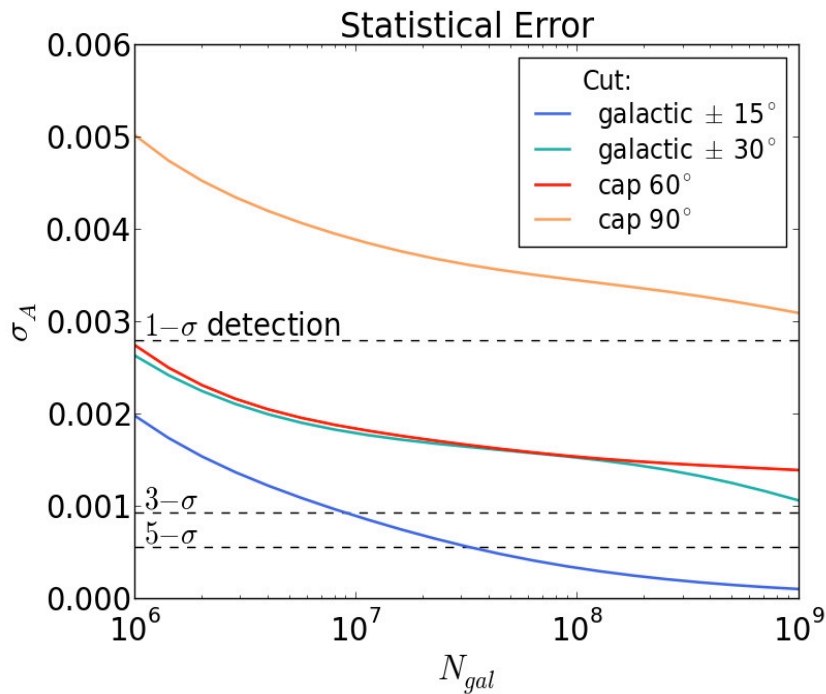


$$d_{obs} = d_{kin} + d_{local}$$

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

- ✓ 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- $\sigma$  and 5- $\sigma$  detections are easily achievable with  $\pm 15$  deg galactic cut and 9M, 30M objects, respectively at the depth of the survey  $z_{med} \sim 0.75$ .
- ✓ 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.