Gravitational dipole analyses with partial-sky coverage data

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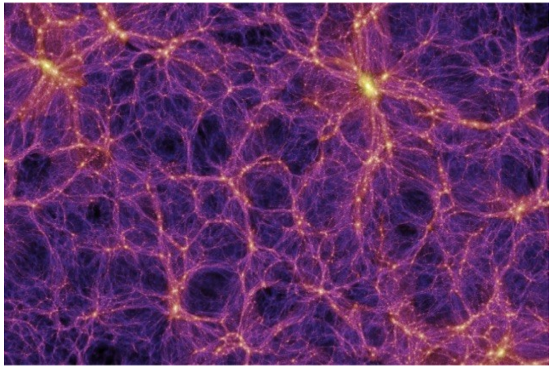
Outline

- Stardard Model of Cosmology
- Cosmic Growth Rate of Structures
- Local Group Dipole
- Methodology
- Results
- Conclusions

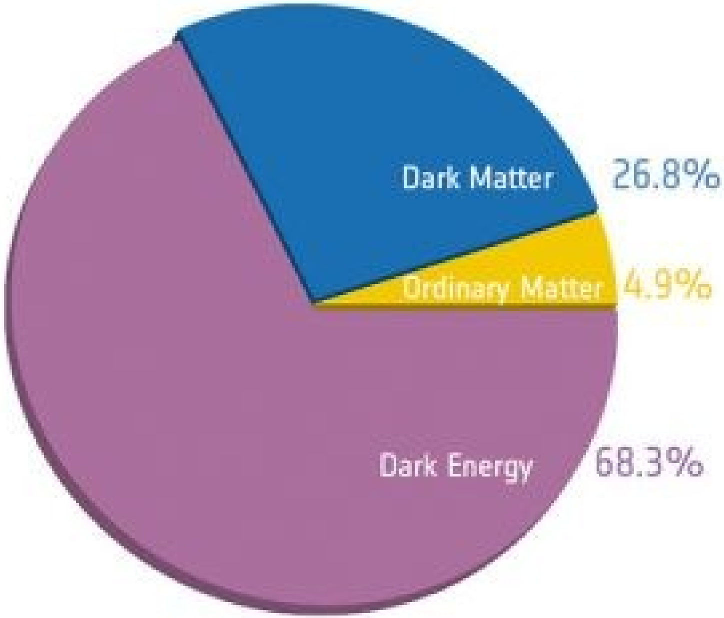
Standard Model of Cosmology

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

General Relativity



Cosmological Principle – Statistical homogeneity and isotropy at large scale (Avila et al. 2018; arXiv:1806.04541).



We still don't know what dark energy and dark matter are.

Cosmic Growth Rate

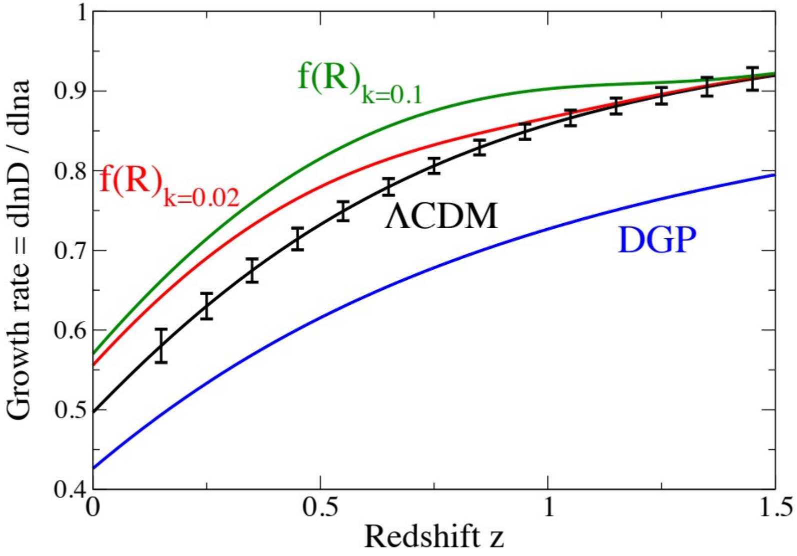
Linear Perturbation Theory

$$\delta(\boldsymbol{r},t) := \frac{\rho(\boldsymbol{r},t)-\bar{\rho}(t)}{\bar{\rho}(t)}$$

$$\frac{\partial^2\delta}{\partial t^2} + \frac{2\dot{a}}{a}\frac{\partial\delta}{\partial t} = 4\pi G\bar{\rho}\delta$$

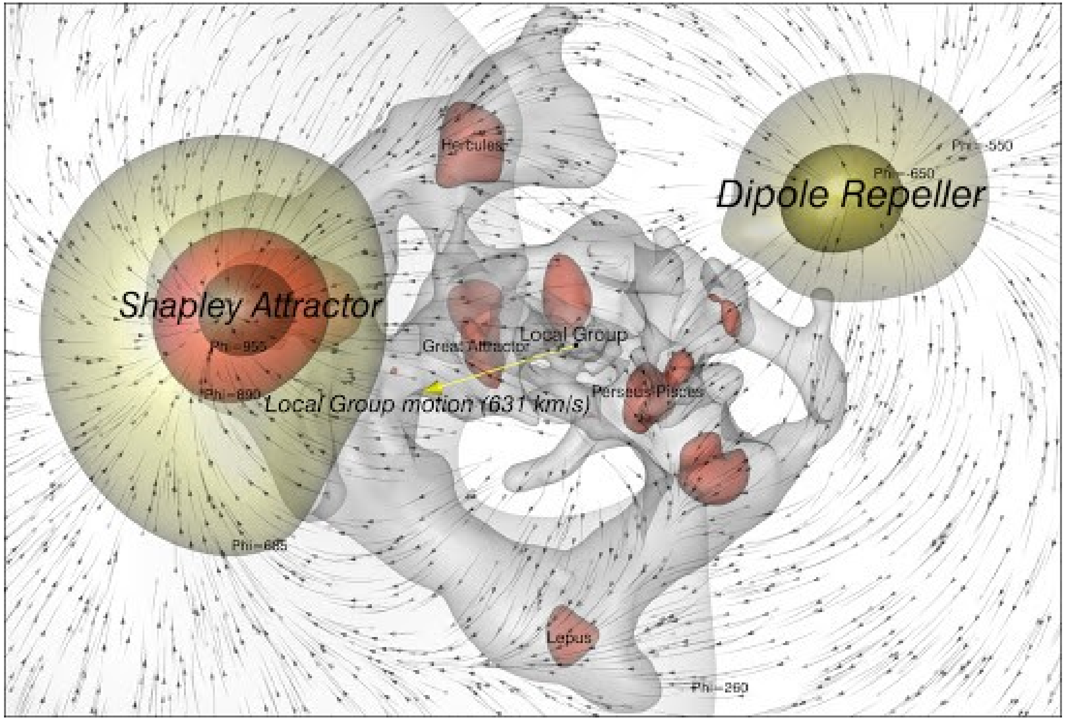
$$\delta(\boldsymbol{x},t) = D_+(t)\,\delta_0(\boldsymbol{x})$$

$$f(a) := \frac{a}{D_+}\frac{\mathrm{d}D_+}{\mathrm{d}a} = \frac{\mathrm{d}\log D_+}{\mathrm{d}\log a}$$



Local Group Dipole

$$\boldsymbol{u}(\boldsymbol{x},t) = \frac{\Omega_{\rm m}^{0.6}(a)}{4\pi}\, a\, H(a) \int \mathrm{d}^3y\, \delta(\boldsymbol{y},t)\, \frac{\boldsymbol{y}-\boldsymbol{x}}{|\boldsymbol{y}-\boldsymbol{x}|^3} \qquad f(a) \approx \Omega_{\rm m}^{\gamma}(a)$$



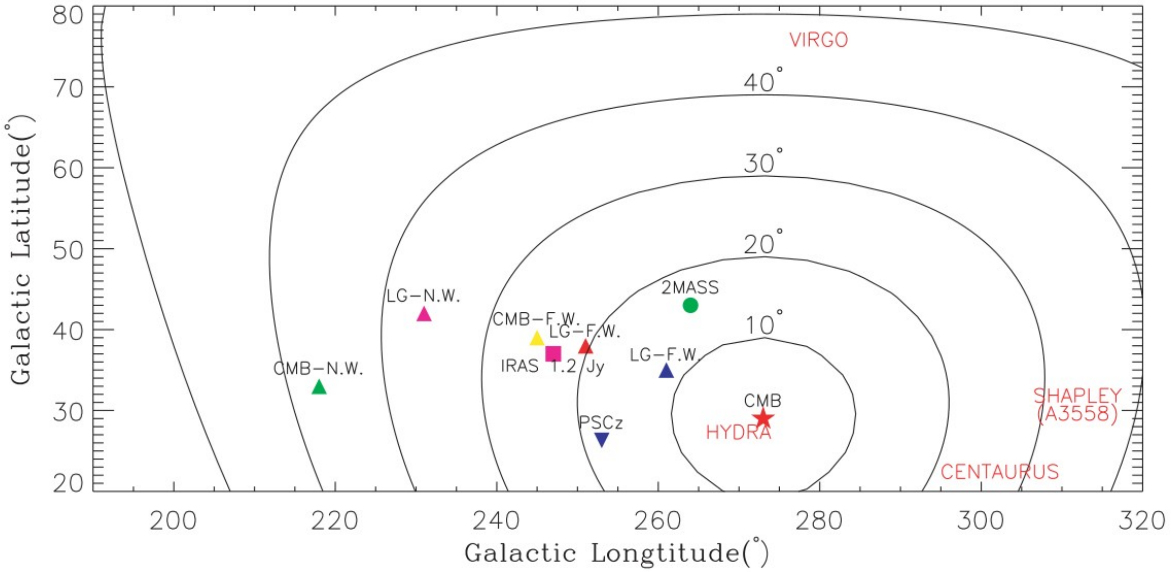
Hoffman et al. (2017)

arXiv:1702.02483

$$\boldsymbol{u}(\boldsymbol{x},t) = \frac{\Omega_{\mathrm{m}}^{0.6}(a)}{4\pi}\, a\, H(a) \int \mathrm{d}^3 y\, \delta(\boldsymbol{y},t)\, \frac{\boldsymbol{y}-\boldsymbol{x}}{|\boldsymbol{y}-\boldsymbol{x}|^3}$$

$$\boldsymbol{v}(\boldsymbol{r}) = \frac{H_0 \beta}{4\pi\langle n\rangle} \int \delta(\boldsymbol{x}) \frac{\boldsymbol{x}}{|\boldsymbol{x}|^3} \mathrm{d}r = \beta \boldsymbol{D}(r)$$

Volume limited survey



Erdoğdu et al. (2006)

$$\boldsymbol{D} = \frac{H_0}{4\pi\langle n\rangle} \sum \frac{\hat{\boldsymbol{r}}}{\phi(r)\, r^2}$$

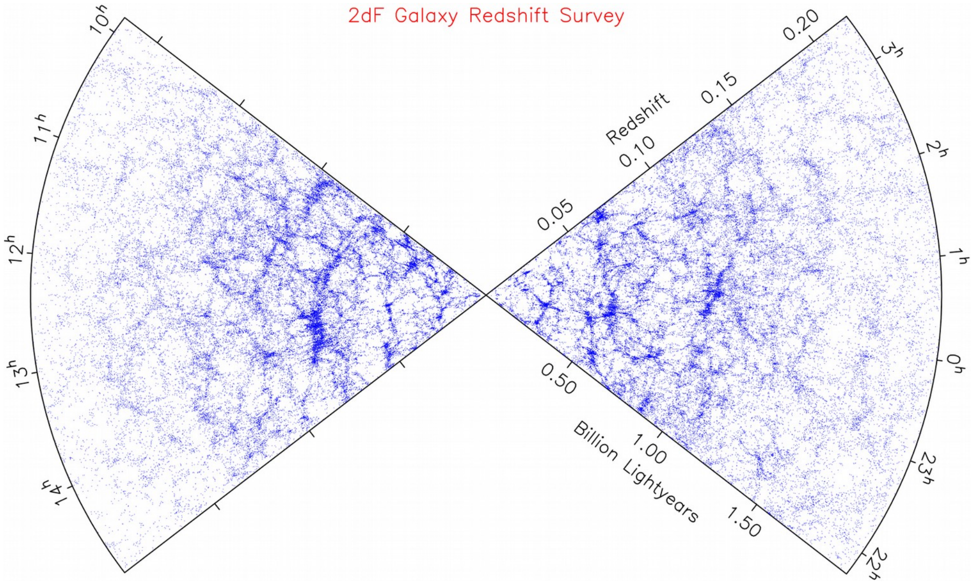
$$\beta \equiv \Omega_{\mathrm{m}}^{0.6}/b$$

Local Group Velocity
+
Gravitational Dipole

Growth Cosmic Rate

Methodology

- Can the dipole be calculated with partial sky coverage?
- What is the error involved?



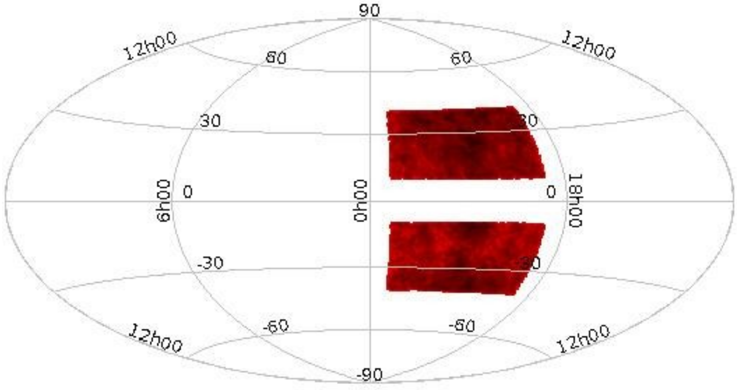
Credit:
http://www.2dfgrs.net/

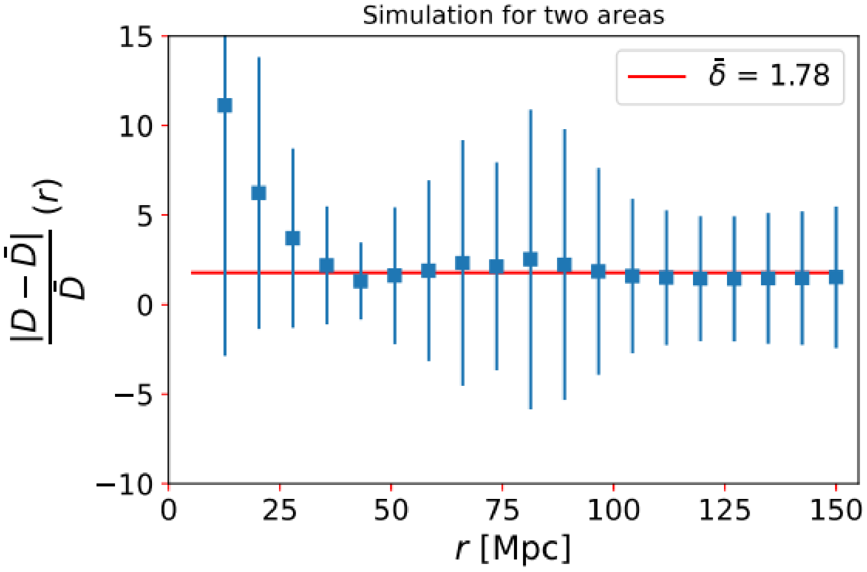
Lognormal Simulations

- We generated a lognormal catalog with a public code (Agrawal et al., 2017; arXiv:1706.09195).
- We select small pieces of the simulation and relocate them randomly in the sky.
- Angular configuration: 30 deg (declination) x 70 deg (Right Ascension).
- The process is done 2000 times so that all possible combinations can be made.

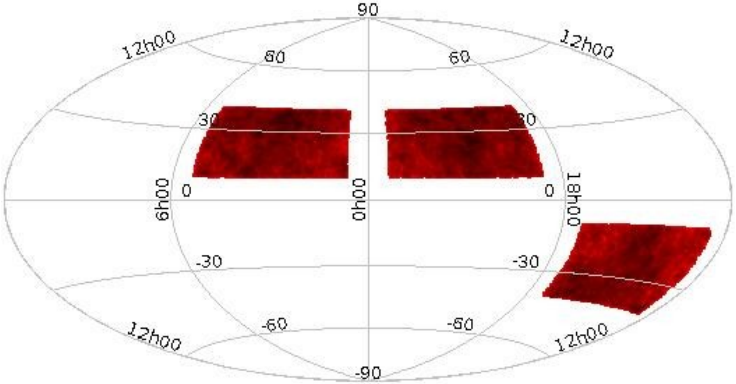
Results

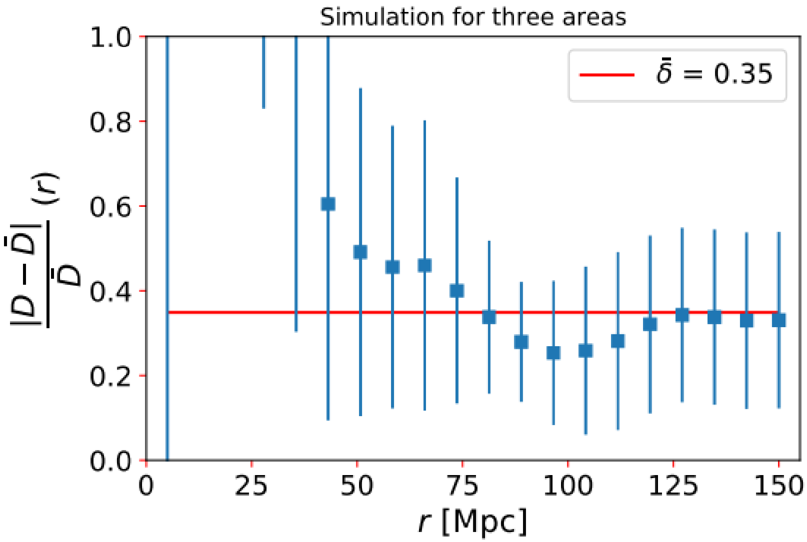
Configuration 1: 28 possible combinations.





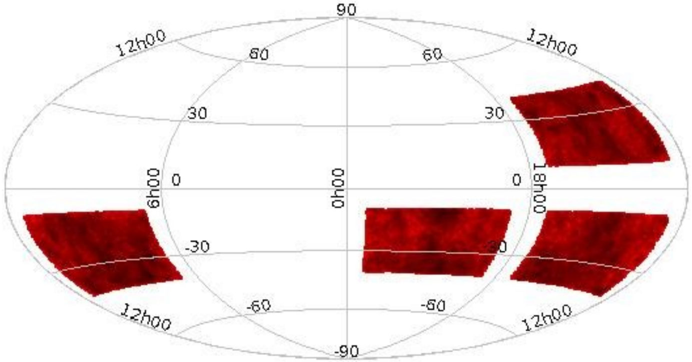
Configuration 2: 56 possible combinations.

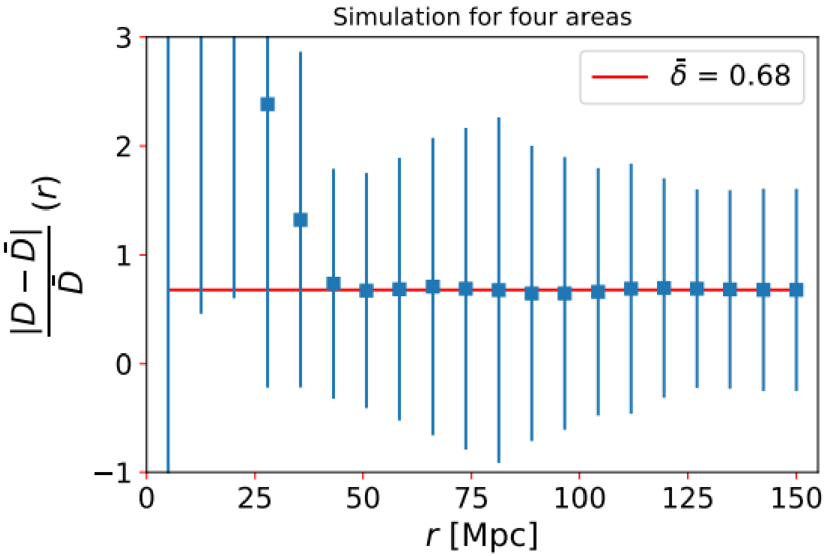




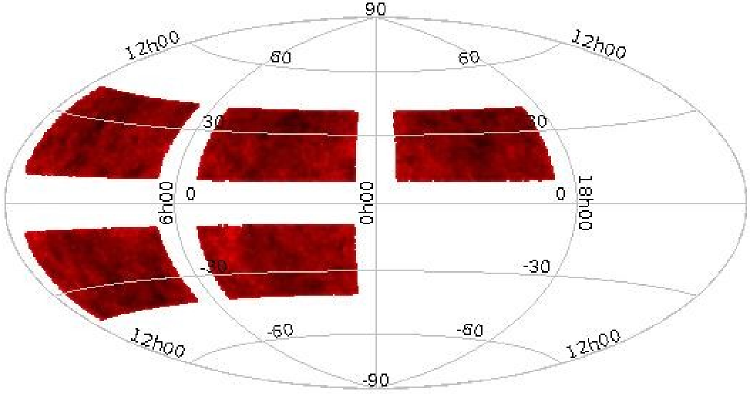
This configuration has the best result, that is, it minimizes the difference in amplitude of the dipole.

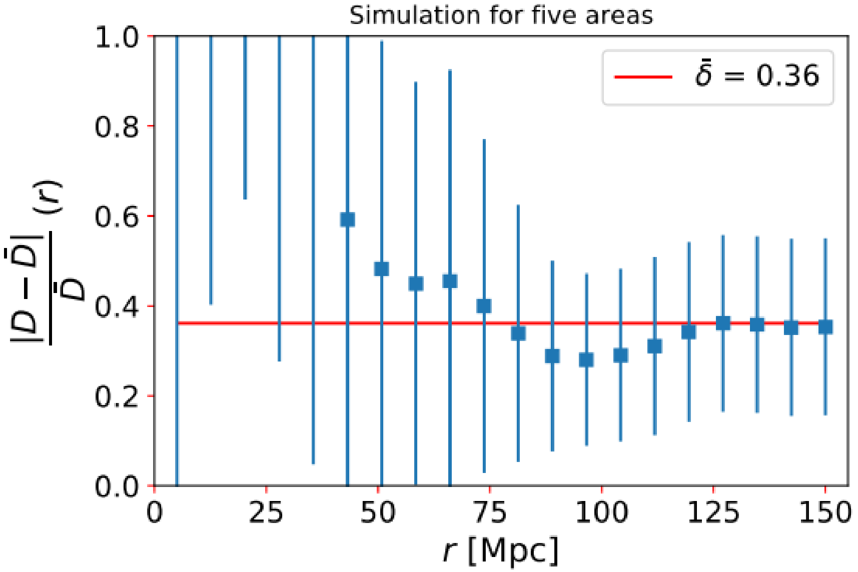
Configuration 3: 70 possible combinations.



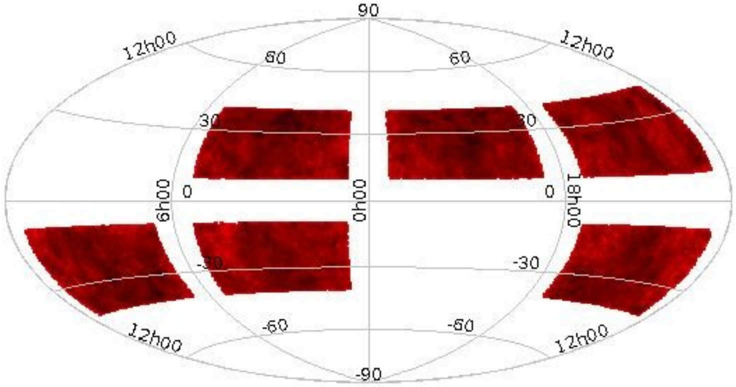


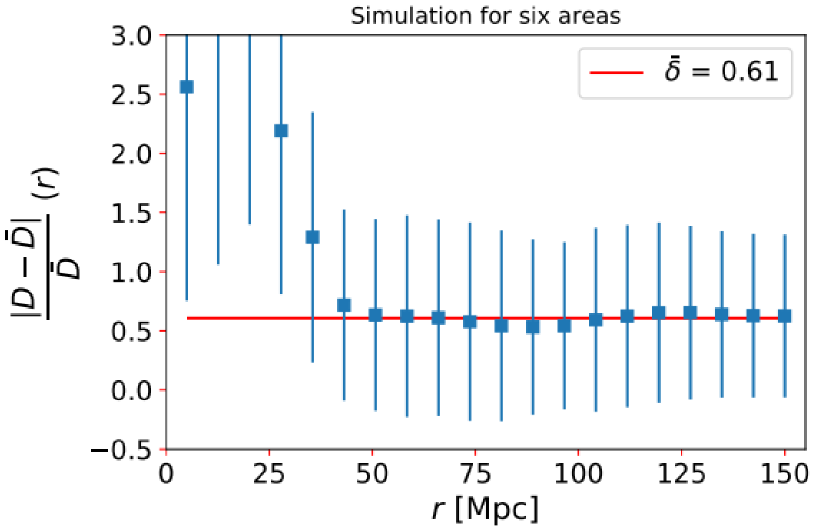
Configuration 4: 56 possible combinations.





Configuration 5: 28 possible combinations.





Summary and Conclusions

- We want to answer if it is possible to calculate the gravitational dipole with partial sky coverage survey to measure the cosmic growth rate.
- We observe that certain configurations decrease the error in the dipole amplitude.
- The result does not seem to depend on the number of objects.
- For current uncertainty measures in β, we need to lower the dipole amplitude difference to 10%. Therefore it is necessary to look for the configuration that minimizes the error.