Relativistic signals in galaxy clustering

Project 56

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Relativistic effects at linear order

The galaxy density field can be written as:

$$\delta_g(k) = \delta_m(k)\left(b_1 + f\mu^2\right)$$

Kaiser (1987)

The galaxy density field can be written as:

$$\delta_g(k) = \delta_m(k)\left(b_1 + f\mu^2\right) - \overbrace{\int_0^r dr' \frac{r-r'}{rr'} \Delta_\Omega(\Phi+\Psi)}^{\text{Lensing}}$$

$$+ \overbrace{\left(1 - \frac{\dot{\mathcal{H}}}{\mathcal{H}^2} - \frac{2}{r\mathcal{H}}\right) v_\parallel + \frac{1}{\mathcal{H}}\dot{v}_\parallel}^{\text{Doppler}} + \overbrace{\frac{1}{\mathcal{H}}\partial_r\Psi}^{\text{grav. redshift}}$$

$$\left.\begin{array}{l} +\Psi - 2\Phi + \dfrac{1}{\mathcal{H}}\dot{\Phi} + \dfrac{2}{r}\displaystyle\int_0^r dr'(\Phi+\Psi) \\ + \left(\dfrac{\dot{\mathcal{H}}}{\mathcal{H}^2} + \dfrac{2}{r\mathcal{H}}\right)\left[\Psi + \displaystyle\int_0^r dr'(\dot{\Phi}+\dot{\Psi})\right] \end{array}\right\} \text{Potential}$$

Kaiser (1987), Yoo et al. (2010), Bonvin & Durrer (2011), Challinor & Lewis (2011)

Relativistic effects at linear order

Linear relativistic Doppler effect and gravitational redshift are given by

$$P_1^{XY}(k,z) \overset{(\mathcal{R}^X=\mathcal{R}^Y)}{=} i\Delta b_1 \frac{\mathcal{H}}{k}\left(f\mathcal{R} + \frac{3}{2}\Omega_m\right) D^2 P(k)$$

with

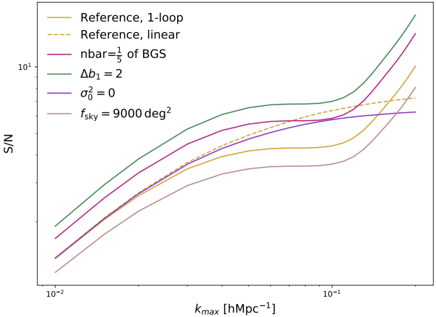
$$\mathcal{R} = 1 - b_e - f - \mathcal{H}^{-1}\partial_t \ln f - (2 - 5s_m)\left(1 - \frac{1}{\mathcal{H}r}\right),$$

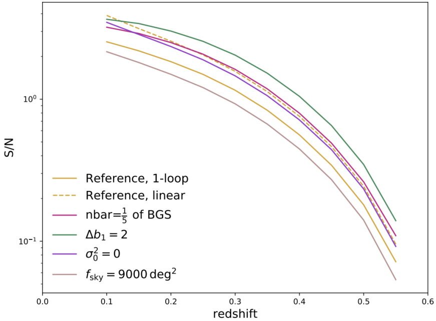
$$b_e(a, >\bar{L}) = \frac{\partial \ln\left[n(a, >\bar{L})\right]}{\partial \ln a} = -(1+z)\frac{\partial \ln n(z, >\bar{L})}{\partial z},$$

$$s_m(a, >\bar{L}) = -\left.\frac{2\partial \ln\left[n(a, >\bar{L})\right]}{5\partial \ln L}\right|_{\bar{L}},$$

See arXiv:2004.08014 for details.

DESI-BGS forecasts for relativistic effects

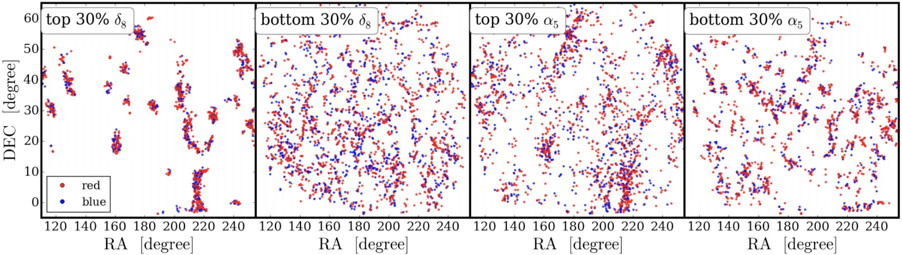




$$\left(\frac{S}{N}\right)^2 = \frac{1}{4\pi^2}\sum_i^{z_{\rm bins}} V(z_i)\int_{k_{\rm min}}^{k_{\rm max}} dk\, k^2 \frac{\left|P_1^{XY}(k,z_i)\right|^2}{\sigma^2_{P_1}(k,z_i)}$$

Beutler et al. JCAP, 2020 (2020)

Optimal sub-samples split



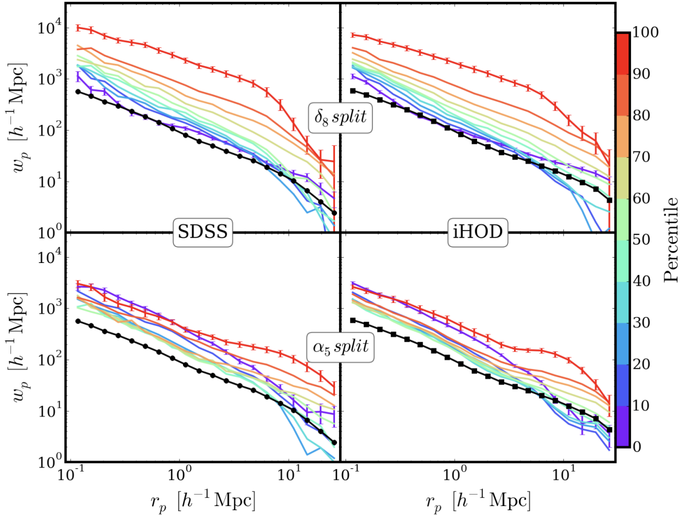
$$\delta_8 = \frac{n_g^8 - \langle n_g \rangle}{\langle n_g \rangle}$$

$$\alpha_5 = \sqrt{q_5^2 (1 + \delta_5)^{-0.55}}$$

$$q_5^2 = 0.5 \left[(\lambda_3 - \lambda_2)^2 + (\lambda_3 - \lambda_1)^2 + (\lambda_2 - \lambda_1)^2 \right]$$

Alam et al. MNRAS 483, 4501 (2019); Heavens & Peacock, MNRAS, 232, 339 (1988)

Optimal sub-samples split



Alam et al. MNRAS 483, 4501 (2019)

Conclusion

1. The project has just started, there is heaps of work to do. Please join if you are interested
   https://desi.lbl.gov/desipub/app/PB/show_project?pid=56
2. Fisher forecasts suggest that we should be able to detect this signal with $> 5\sigma$. But tests on mock catalogs are needed to investigate this further.
3. We need BGS mock catalogs including relativistic effects to test our modelling.