Internship Defense

M2 Astrophysics

Modeling non-linear redshift-space distortions induced by galaxy peculiar velocities

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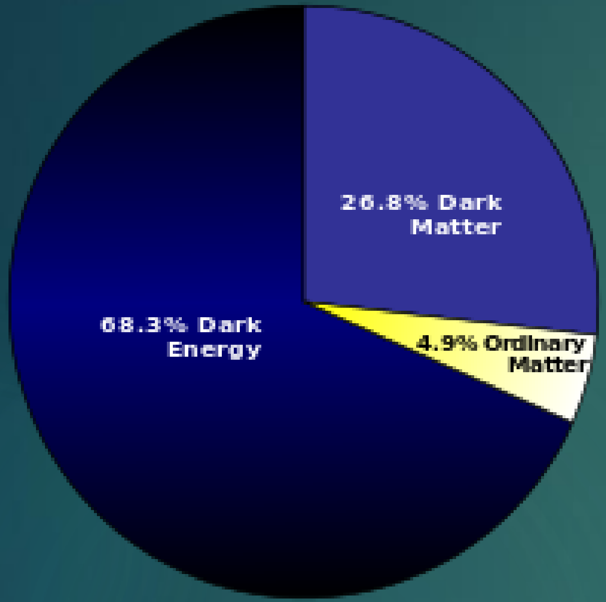
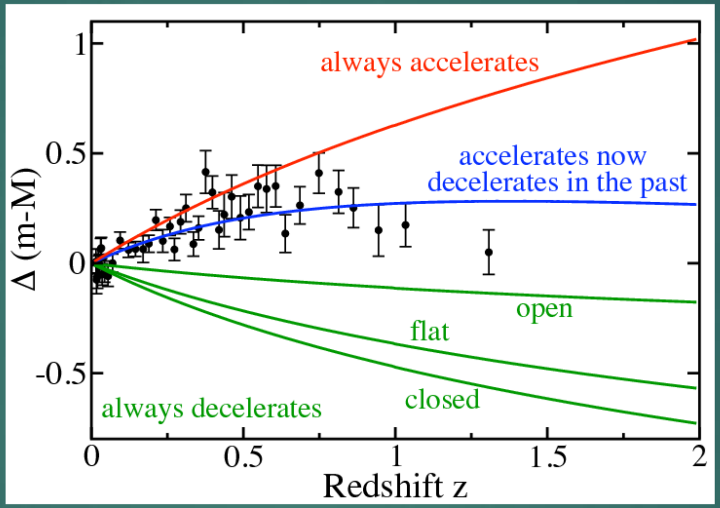
Introduction

Current cosmological model

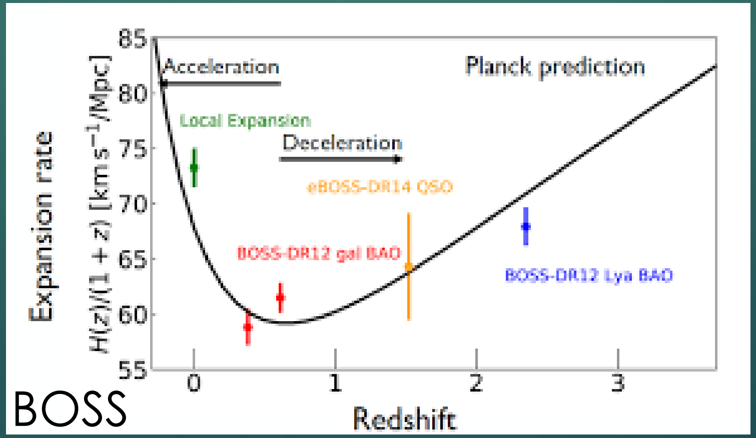


- Expanding Universe, today dominated by Dark Energy
- Two types of matter : Dark and baryonic matter
- Ruled by General Relativy (GR)
- Homogeneous and Isotropic on large scales

- Evidence of an acceleration of the expansion by Supernovae 1a and BAO

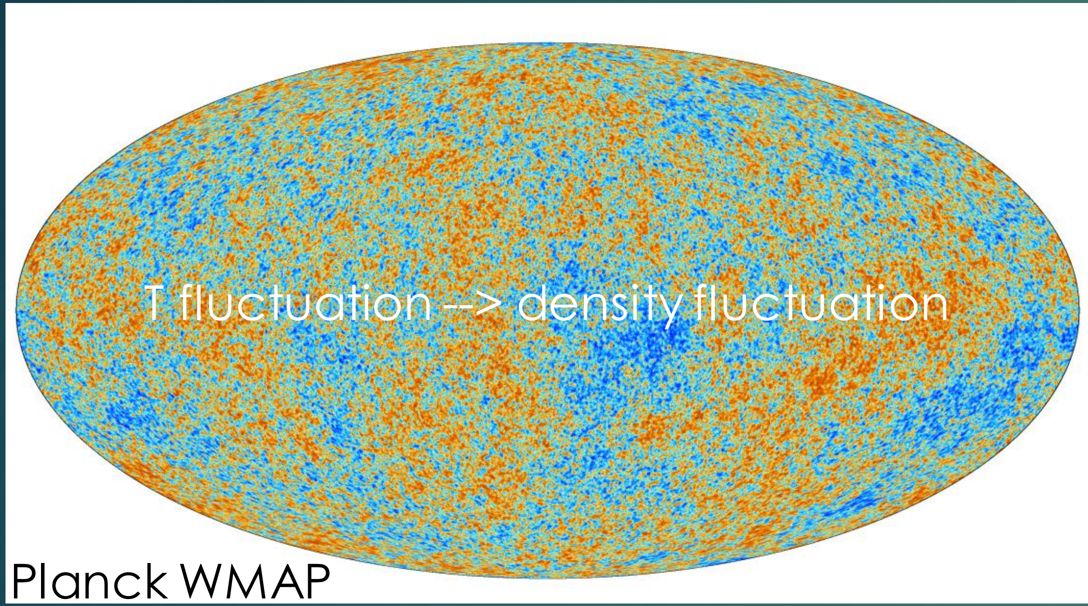


- Can be explained by Dark Energy
- Or deviation from GR ??



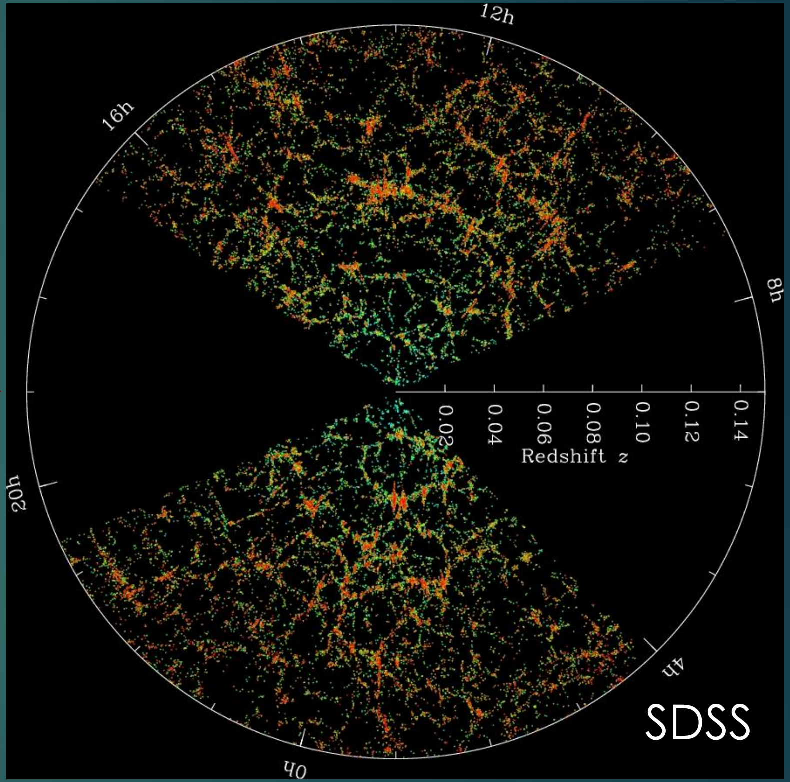
Seek probes to test gravitation and the dynamics of the Universe on large scales

Large Scales Structures (LSS)



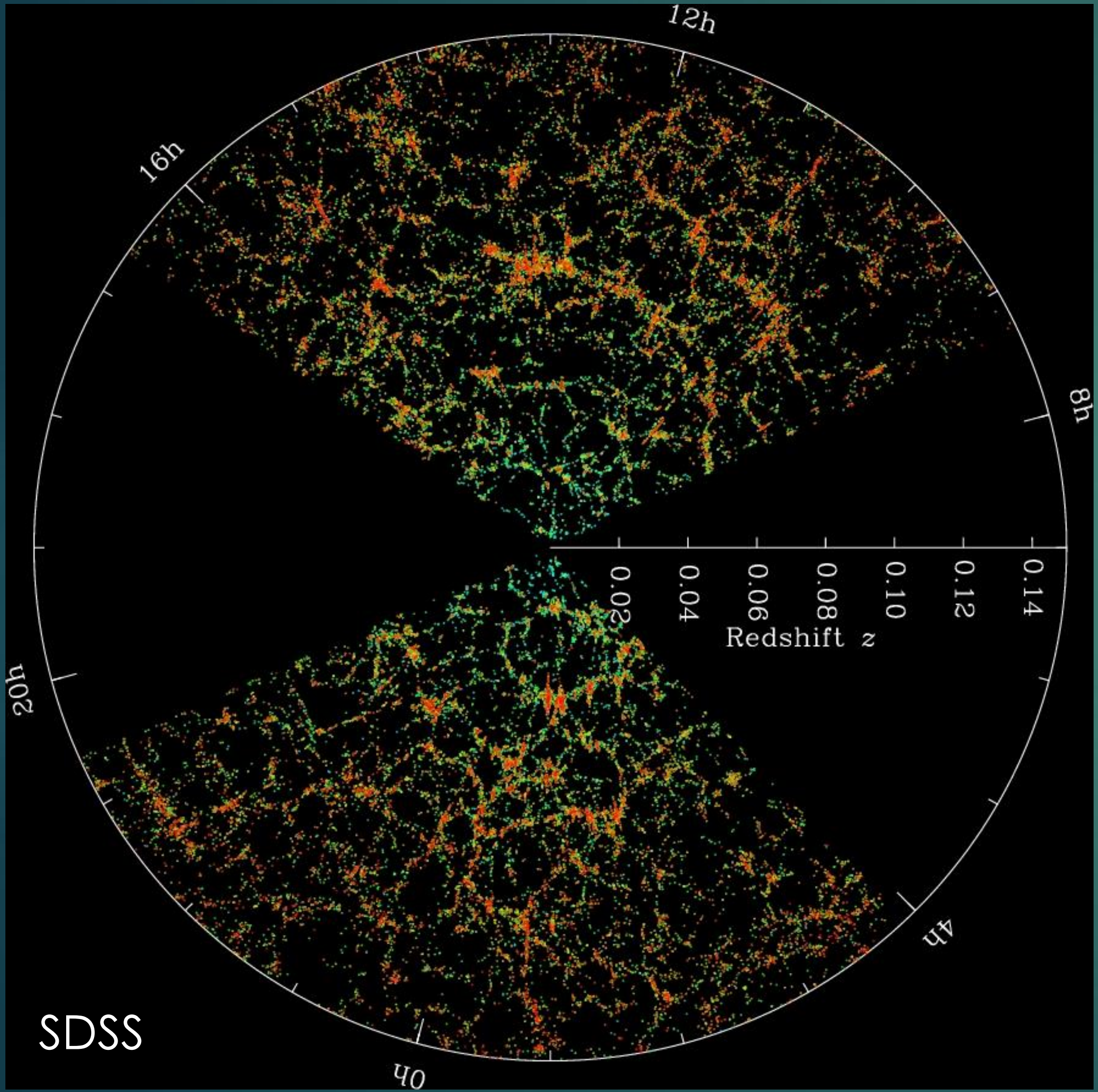
Initial density fluctuations

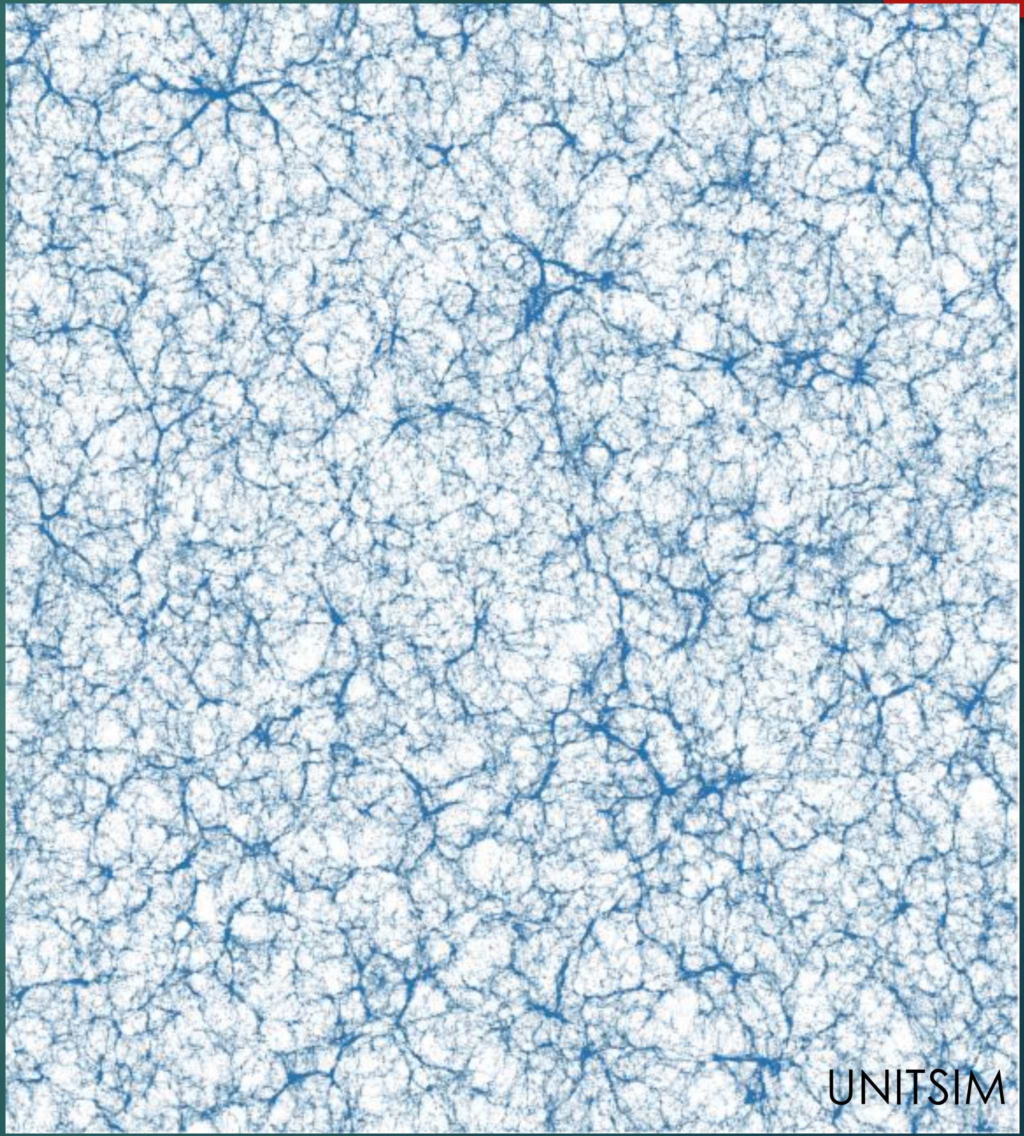
Growth under gravity



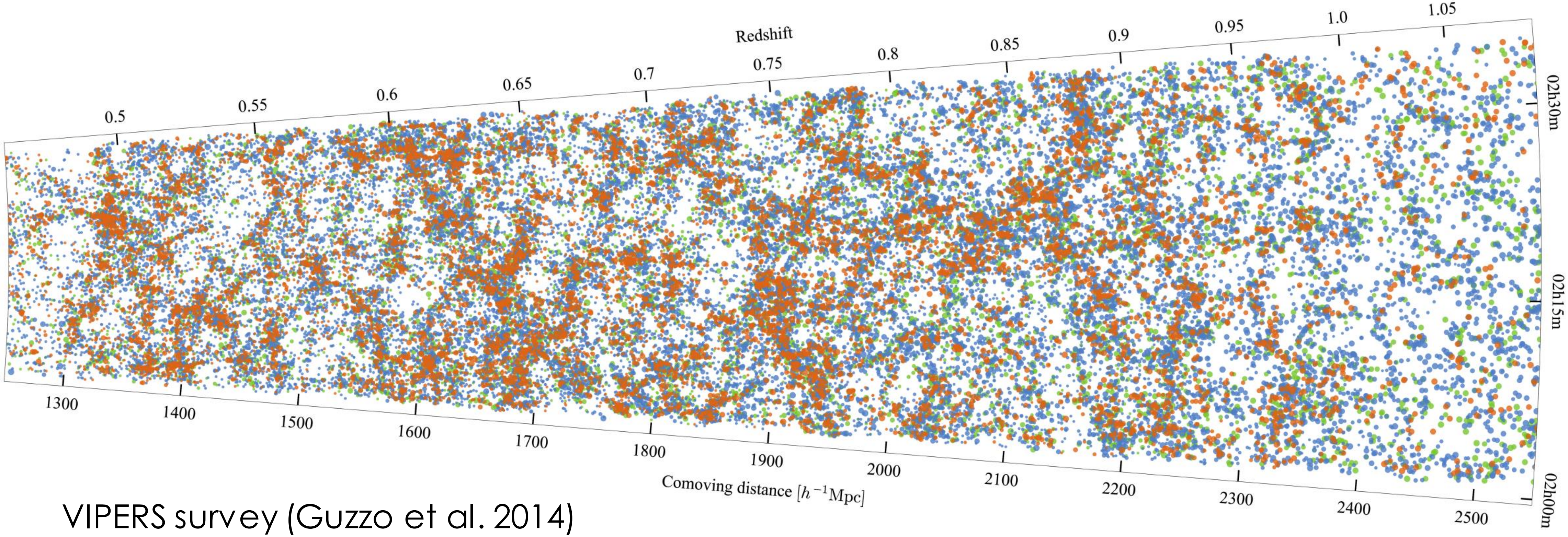
Formation of stars, galaxies, clusters, ...

Galaxy redshift surveys Simulation





Galaxy Redshift Surveys



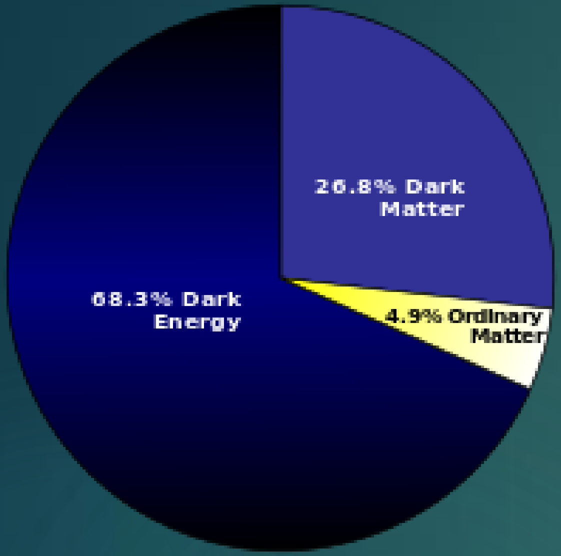
VIPERS survey (Guzzo et al. 2014)

Estimation of distances with spectroscopic redshift

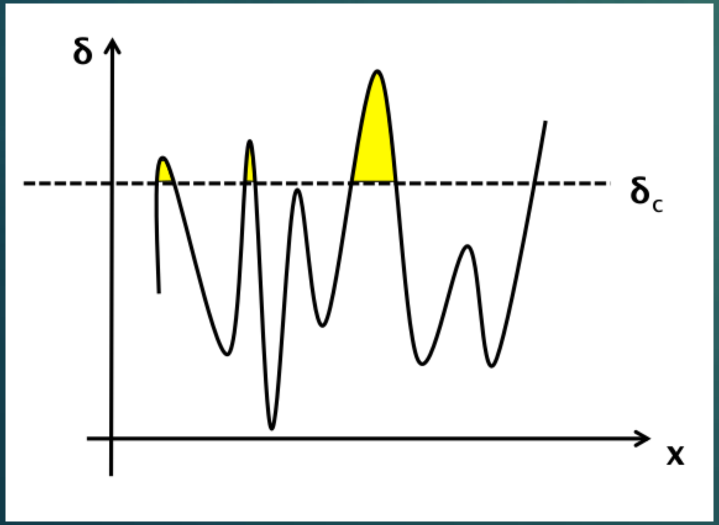
Sensitive to galaxies peculiar motions

$$\mathbf{s} = \mathbf{x} + \frac{\mathbf{v}(\mathbf{x}) \cdot \hat{\mathbf{x}}}{aH}$$
$$= \mathbf{x} + f\left[\mathbf{u}(\mathbf{x}) \cdot \hat{\mathbf{x}}\right], \qquad \mathbf{u} \equiv \frac{\mathbf{v}}{aHf}$$

Galaxy Bias



Galaxy field ≠ True matter field



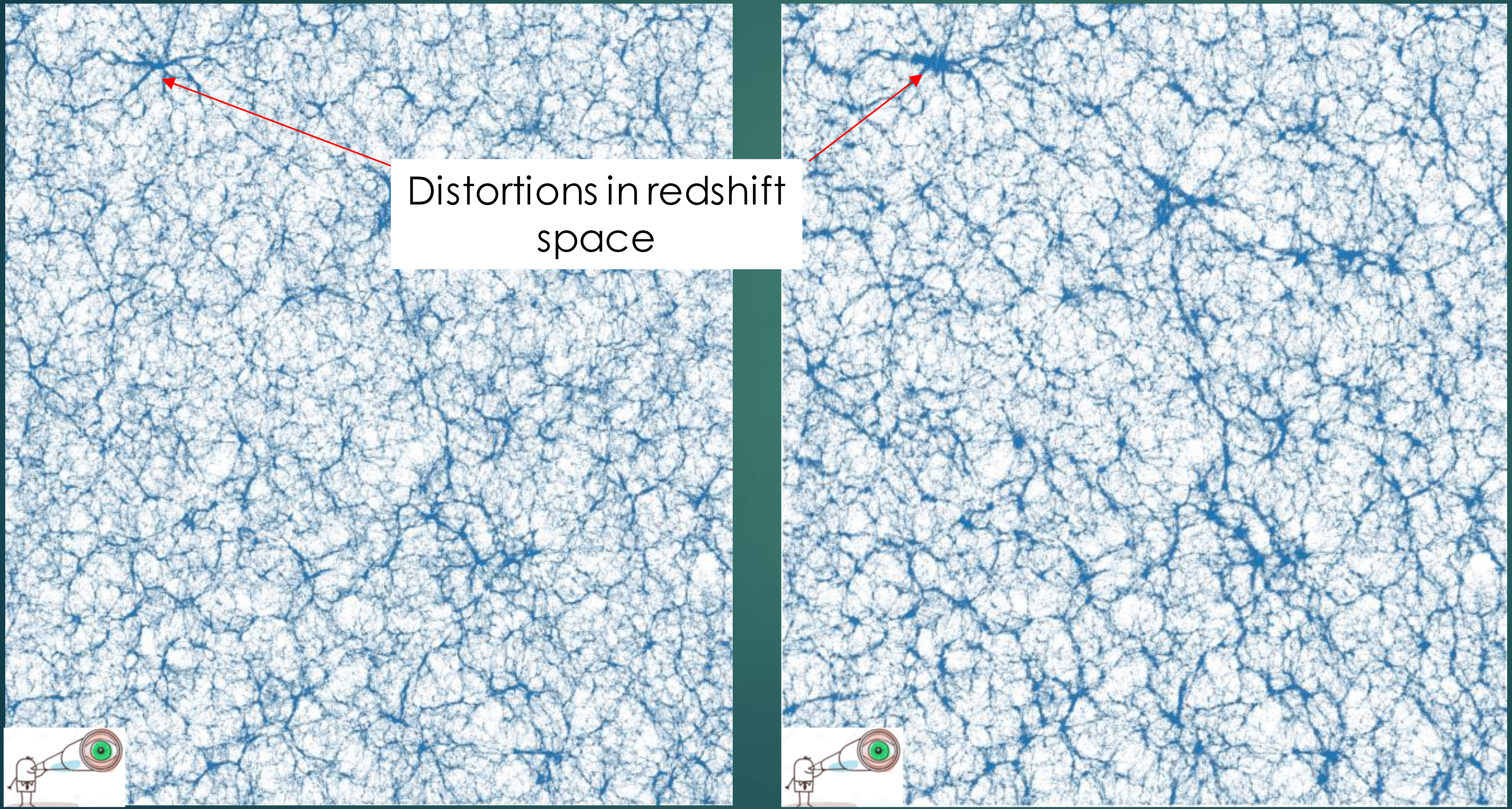
If δ > 1.68

collapse and create structures (dense peaks)

Observed LSS with redshift surveys

Real space

Redshift space



Galaxies peculiar velocities

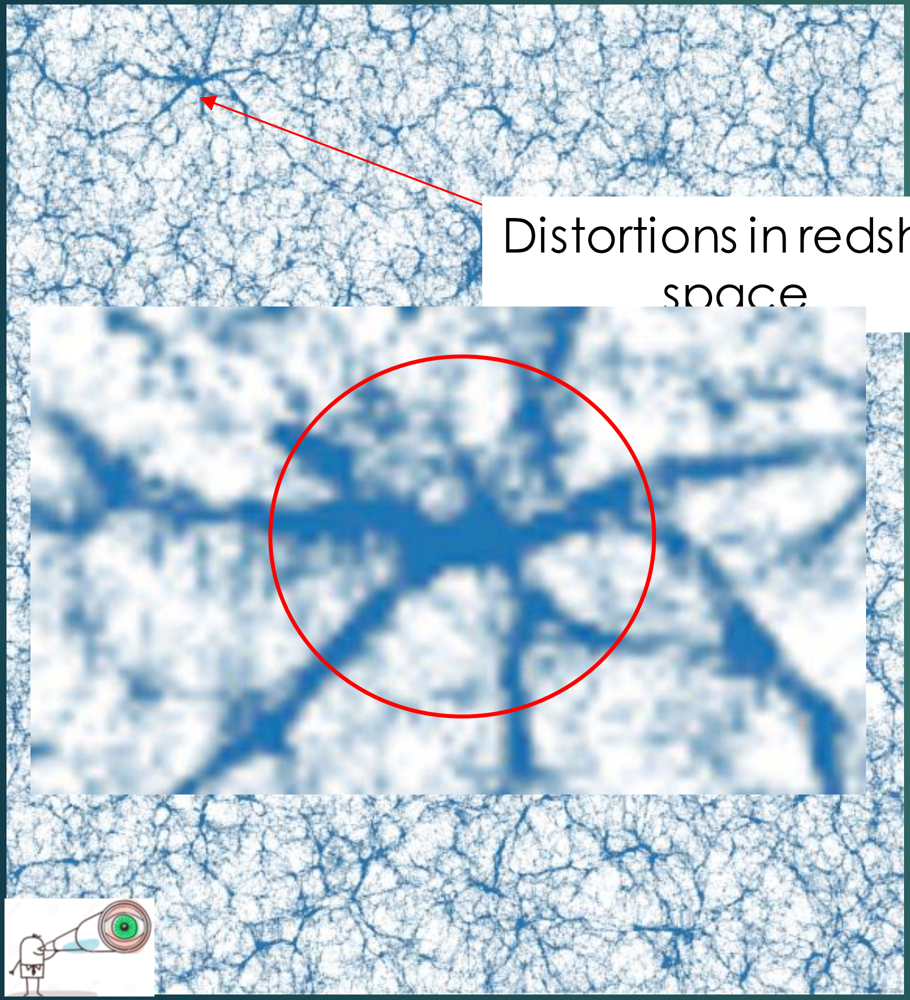
$$z = (1 + z_{cosmo})\left(1 + \frac{v \cdot \hat{l}}{c}\right)$$

$$\begin{aligned} \mathbf{s} &= \mathbf{x} + \frac{\mathbf{v}(\mathbf{x}) \cdot \hat{l}}{aH} \\ &= \mathbf{x} + f\left[\mathbf{u}(\mathbf{x}) \cdot \hat{l}\right], \qquad \mathbf{u} \equiv \frac{\mathbf{v}}{aHf} \end{aligned}$$

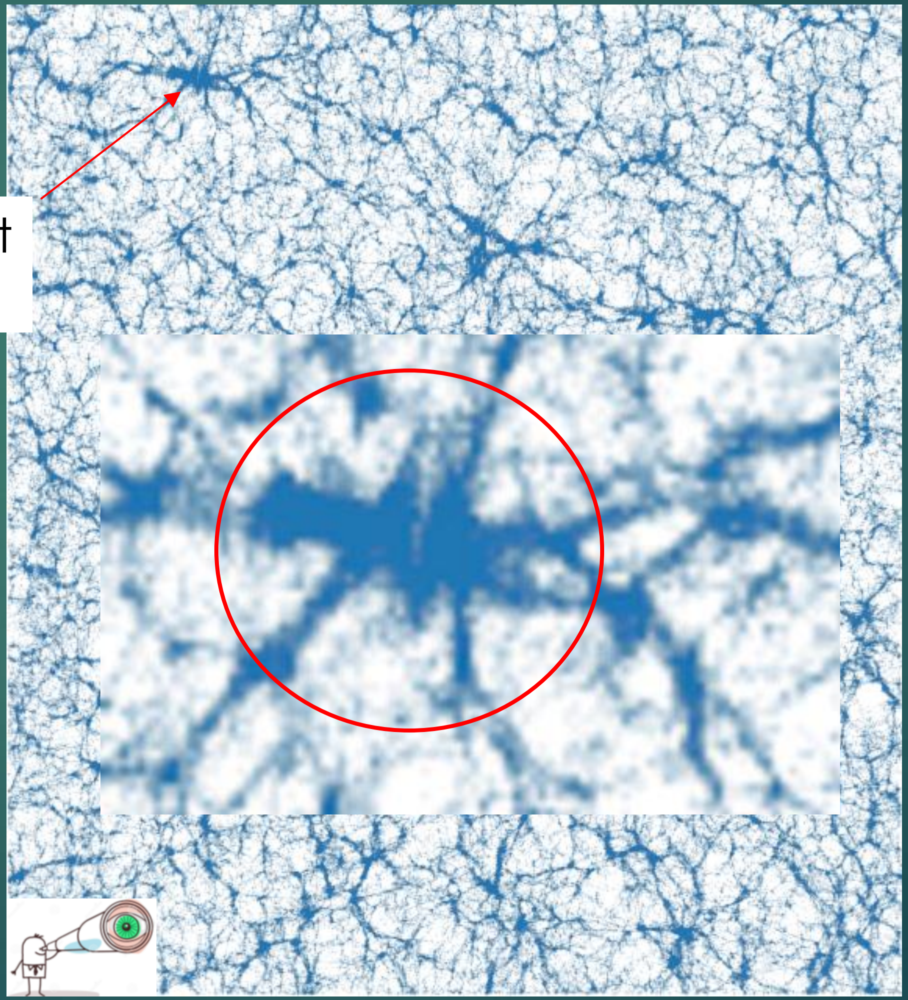
Affects the apparent distances along the line of sight (los)

Observed LSS with redshift surveys

Real space



Redshift space



Distortions in redshift space

Galaxies peculiar velocities

$$z = (1 + z_{cosmo})\left(1 + \frac{v \cdot \hat{l}}{c}\right)$$

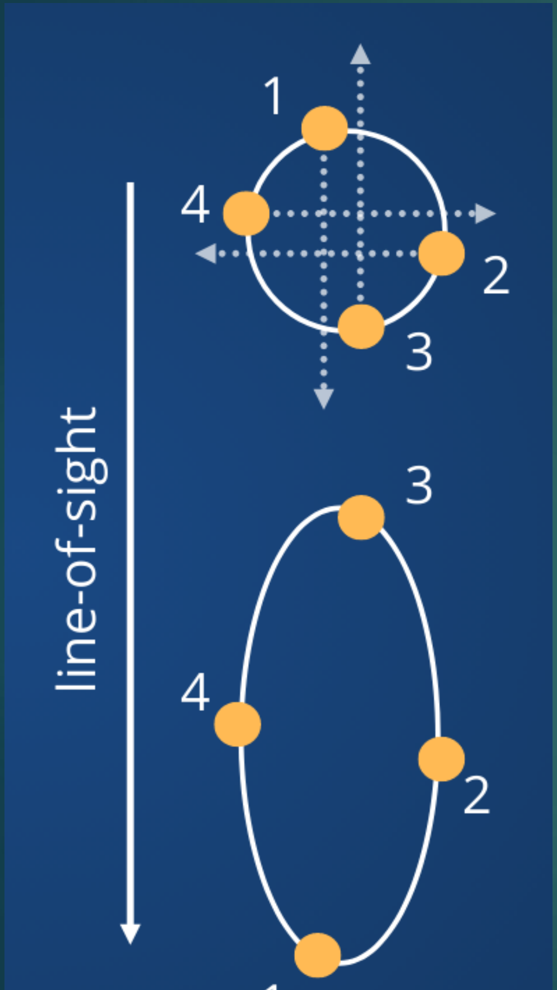
$$\begin{aligned} \mathbf{s} &= \mathbf{x} + \frac{\mathbf{v}(\mathbf{x}) \cdot \hat{l}}{aH} \\ &= \mathbf{x} + f\left[\mathbf{u}(\mathbf{x}) \cdot \hat{l}\right], \qquad \mathbf{u} \equiv \frac{\mathbf{v}}{aHf} \end{aligned}$$

Affects the apparent distances along the line of sight (los)

RSD EFFECT

Small scales : Fingers of God
~Mpc (haloes)

Large scales : Kaiser effect
> ~10 Mpc



Kuruvilla et al.

Non linear effect:

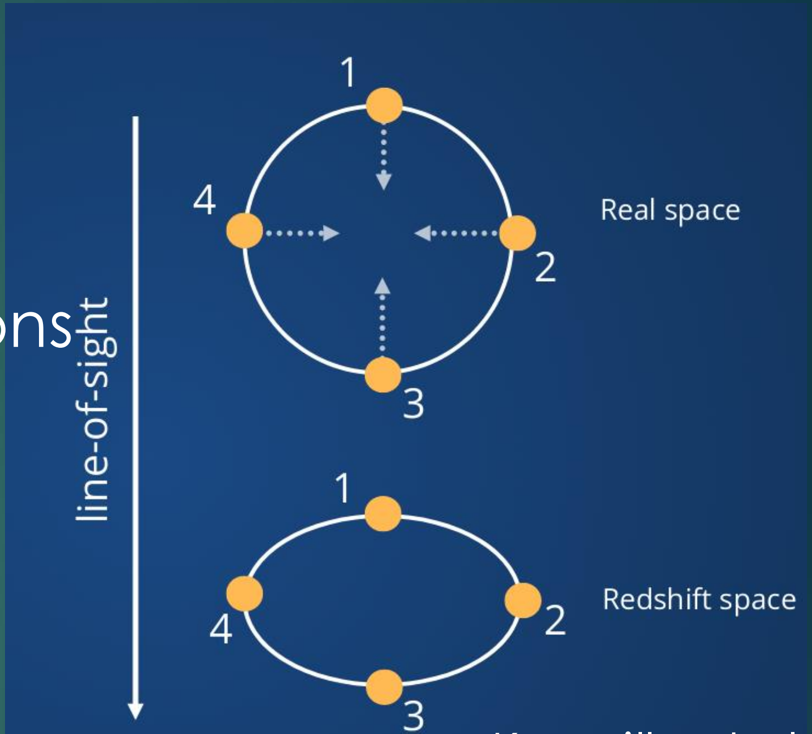
- Random motions

- Elongation along LOS

Linear effect:

- Coherent motions

- Squashing effect along LOS

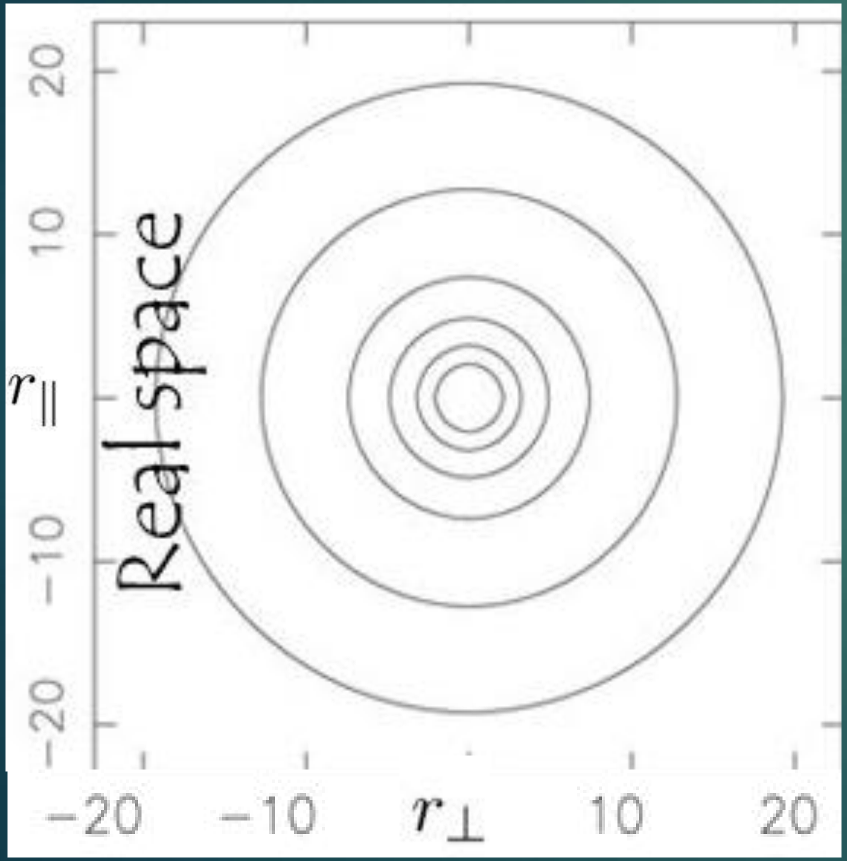


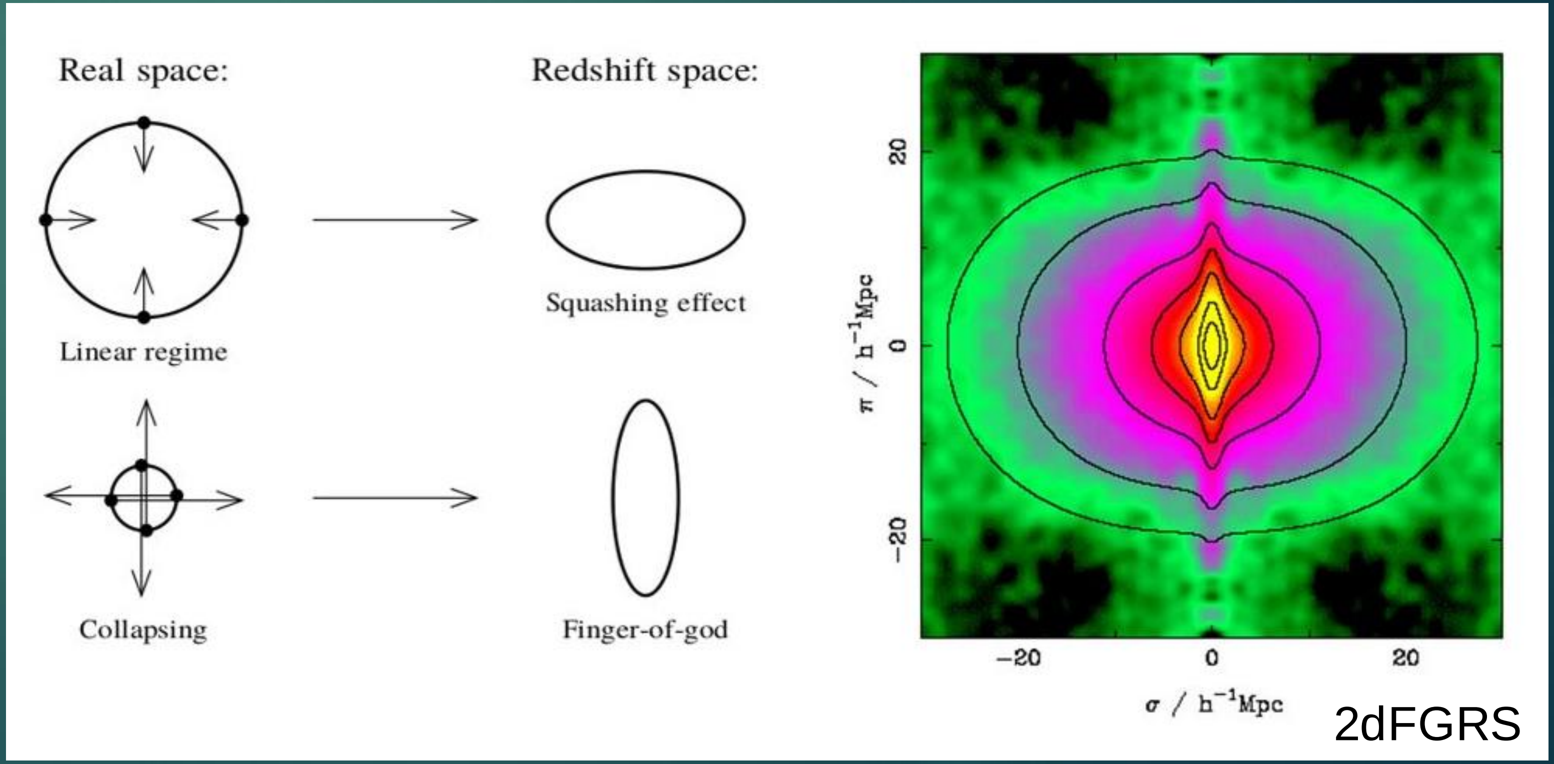
Kuruvilla et al.

=> Anisotropies between parallel and perpendicular component
=> Characterize in redshift spectroscopic surveys

Two-points correlation function

$$dP(\boldsymbol{r}) = \bar{n}^2(1 + \xi(\boldsymbol{r})dV_1 dV_2$$





Growth rate

In linear theory:

$$\nabla \boldsymbol{u} = -aHf\delta$$

Growth Factor

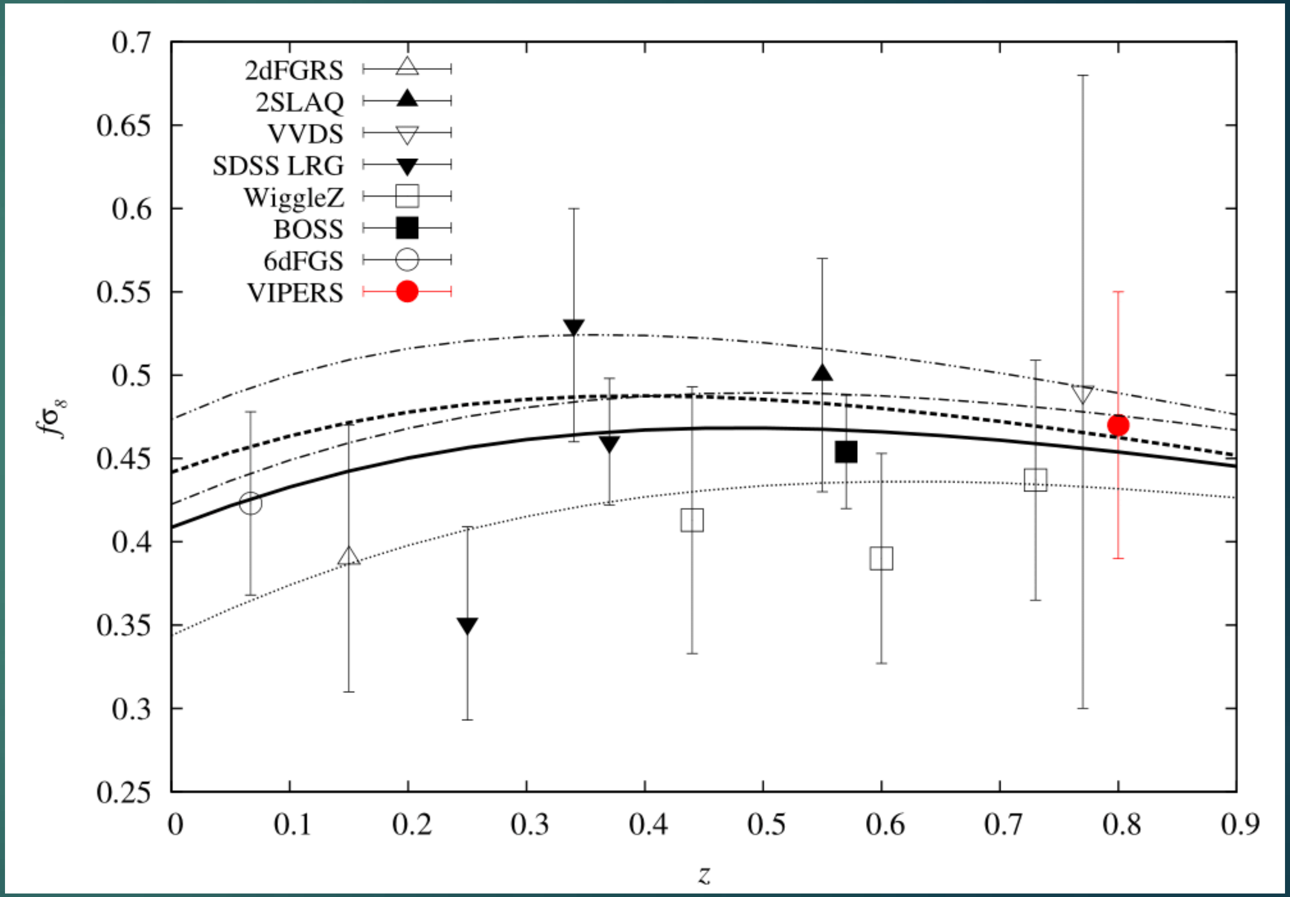
$$f(a) = \frac{d\ln D}{d\ln a}$$

Growth rate

f(a) describes a which speed structure growth

Predicted by GR: $f(z) \approx \Omega_M(z)^{0.55}$

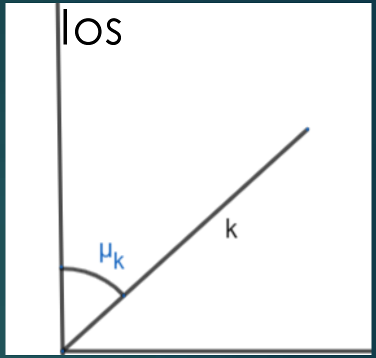
Test RG a large scale



Kaiser linear model

Number of galaxies is conserved

$$n^s(\boldsymbol{s})\, d^3 s = n(\boldsymbol{r})\, d^3 r$$



Small perturbation
Small velocity variation
Characteristic scale perburbations is small regarding the distance from us

$$\delta^s(\mathbf{k}) = \left(1 + f\mu^2\right)\delta(\mathbf{k})$$

$$P(k) = \langle \delta(\boldsymbol{k}_1)\delta(\boldsymbol{k}_2)\rangle$$

$$P^s(k,\mu) = \left(1 + f\mu^2\right)^2 P(k)$$

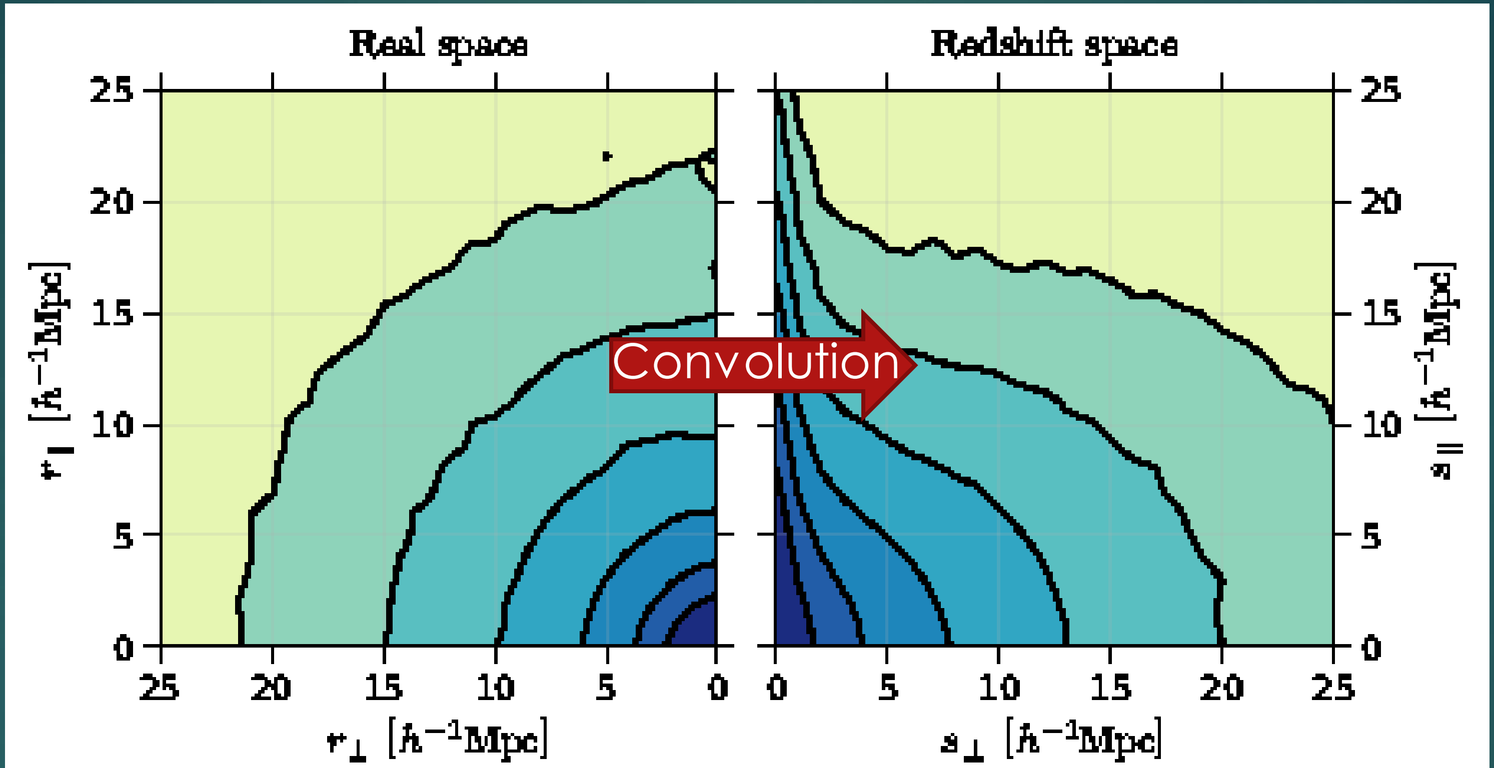
Assuming a linear bias

$$P_g^s(\boldsymbol{k}) = (1 + \beta\mu^2)^2 P(k)$$

$$\beta = f/b$$

Streaming model

Scoccimaro 2004, Fisher 1995, Peebles 1980



$$1 + \xi_s(s_\parallel, s_\perp) = \int_{-\infty}^{\infty} dr_\parallel [1 + \xi(r)] \mathcal{P}(r_\parallel - s_\parallel, \boldsymbol{r})$$

2PCF in redshift space

2PCF in real space

Convolution Kernel varying with scale

Gaussian streaming model

This model assumes *P* is Gaussian:

$$1 + \xi_s(s_\parallel, s_\perp) = \int_{-\infty}^{\infty} dr_\parallel \; [1 + \xi(r)] \; \mathcal{P}(r_\parallel - s_\parallel, \boldsymbol{r})$$

$$\mathcal{P}(v_{12} = s_\parallel - r_\parallel, \boldsymbol{r}) = \frac{1}{\sqrt{2\pi\sigma_{12}(\boldsymbol{r}, \mu_r)}} \; \exp\left[-\frac{s_\parallel - r_\parallel - \mu_r v_{12}(\boldsymbol{r})}{2\sigma_{12}^2(\boldsymbol{r}, \mu_r)} \right]$$

pairwise velocity probability distribution function

But need to evaluate its moments !

$\mu_r v_{12}(\boldsymbol{r})$ $\sigma_{12}^2(\boldsymbol{r}, \mu_r)$

Scoccimaro 2004, Fisher 1995, Peebles 1980

Fisher 1995 linear prediction

Velocity/density coupling

$$\langle (\vec{v}\,' - \vec{v})\,(1+\delta)\,(1+\delta\,')\rangle$$

Velocity/Velocity coupling

$$\langle \vec{v}_i \vec{v}_j\,' \rangle$$

$$\boldsymbol{v}_{12}(\boldsymbol{r}) = -\hat{r}\frac{fb}{\pi^2}\int_0^\infty dk\ k\ P^r_m(k) j_1(kr)$$

$$\Psi_{\parallel}(\boldsymbol{r}) = \frac{f^2}{2\pi^2}\int_0^\infty dk P^r_m(k)\left[j_o(kr) - \frac{2j_1(kr)}{kr}\right]$$

$$\Psi_{\perp}(\boldsymbol{r}) = \frac{f^2}{2\pi^2}\int_0^\infty dk P^r_m(k)\frac{j_1(kr)}{kr}$$

$$\sigma^2_{12}(\boldsymbol{r}, \mu^2_r) = 2\left[\sigma^2_v - \mu^2_r\Psi_{\parallel}(r) - (1-\mu^2_r)\Psi_{\perp}(r)\right]$$

Convolution Lagrangian Perturbation Theory

Eulerian (x)– Lagrangian (q) mappping

$$\boldsymbol{x}(\boldsymbol{q},t) = \boldsymbol{q} + \Psi(\boldsymbol{q},t)$$ → Displacement field

Conservation equation

$$[1+\delta_m(\boldsymbol{x},t)]d^3x = [1+\delta_m(\boldsymbol{q},t_0)]d^3q$$

$$1+\delta_m(\boldsymbol{x},t) = [1+\delta_m(\boldsymbol{q},t_0)]\left|\frac{d^3\boldsymbol{x}}{d^3\boldsymbol{q}}\right|^{-1}$$

$$1+\delta(\boldsymbol{x},t) = \int d^3q\ \delta_D^3[\boldsymbol{x}-\boldsymbol{q}-\Psi(\boldsymbol{q},t)]$$

$$1+\xi(\boldsymbol{r}) = \int d^3q\ \boxed{M_0(\boldsymbol{r},\boldsymbol{q})}$$

$$v_{12,n}(\boldsymbol{r}) = [1+\xi(r)]^{-1}\int d^3q\ M_{1,n}(\boldsymbol{r},\boldsymbol{q})$$

$$\sigma^2_{12,nm}(\boldsymbol{r}) = [1+\xi(r)]^{-1}\int d^3q\ M_{2,nm}(\boldsymbol{r},\boldsymbol{q})$$

M1 et M2 are 1st and 2nd derivative of M_0

$$1+\xi_X(\boldsymbol{r}) = \int d^3q \boxed{\int \frac{d^3k}{(2\pi)^3} e^{i\boldsymbol{k}\cdot(\boldsymbol{q}-\boldsymbol{r})} \int \frac{d\lambda_1}{2\pi}\frac{d\lambda_2}{2\pi}\ \tilde{F}_1\tilde{F}_2 K(\boldsymbol{q},\boldsymbol{k},\lambda_1,\lambda_2)}$$

$$K(\boldsymbol{q},\boldsymbol{k},\lambda_1,\lambda_2) = \left\langle e^{i(\lambda_1\delta_1+\lambda_2\delta_2+\boldsymbol{k}\cdot\vec{\Delta})}\right\rangle \quad \text{and} \quad \Delta \equiv \vec{\Psi}_2 - \vec{\Psi}_1$$

CLPT Predictions

Cumulant expansion

$$\left\langle e^{iX} \right\rangle = \exp\left[\sum_{N=1}^{\infty} \frac{i^N}{N!} \langle X^N \rangle_c \right]$$

$$M_0 = \frac{1}{(2\pi)^{3/2}|A|^{1/2}} e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T \mathbf{A}^{-1} (\boldsymbol{r}-\boldsymbol{q})} \times \Big\{ 1 + \langle F' \rangle^2 \xi_R - 2 \langle F' \rangle U_i g_i + \frac{1}{2} \langle F'' \rangle^2 \xi_R - 2 \langle F' \rangle \langle F'' \rangle \xi_R U_i g_i$$
$$- [\langle F'' \rangle + \langle F' \rangle^2] \underline{U_i U_j} G_{ij} + \frac{1}{6} \underline{W_{ijk}} \Gamma_{ijk} - \langle F' \rangle \underline{A^{10}_{ij}} G_{ij} - \langle F'' \rangle U^{20}_i g_i - \langle F' \rangle^2 U^{11}_i g_i + O(P_L^3) \Big\} \tag{76}$$

$$M_{1,n} = \frac{f^2}{(2\pi)^{3/2}|A|^{1/2}} e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T \mathbf{A}^{-1} (\boldsymbol{r}-\boldsymbol{q})} \times \Big\{ 2 \langle F' \rangle \dot{U}_n - g_i \dot{A}_{in} + \langle F'' \rangle \dot{U}^{20}_n + \langle F' \rangle^2 \dot{U}^{11_n} + 2 \langle F' \rangle \langle F'' \rangle \xi_L \dot{U}_n$$
$$- 2 \langle F' \rangle g_i \dot{A}^{10}_{in} - \frac{1}{2} G_{ij} \dot{W}_{ijn} - 2[\langle F'' \rangle + \langle F' \rangle^2] g_i U_i \dot{U}_n - \langle F' \rangle^2 \xi_L g_i \dot{A}_{in} - 2 \langle F' \rangle G_{ij} U_i \dot{A}_{in} + O(P_L^3) \Big\} \tag{77}$$

$$M_{2,nm} = \frac{f^2}{(2\pi)^{3/2}|A|^{1/2}} e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T \mathbf{A}^{-1} (\boldsymbol{r}-\boldsymbol{q})} \times \{ 2[\underline{\langle F' \rangle^2} + \underline{\langle F'' \rangle}] \dot{U}_n \dot{U}_m - 2 \langle F' \rangle (\dot{A}_{in} g_i \dot{U}_m + \dot{A}_{im} g_i \dot{U}_n)$$
$$- \dot{A}_{im} \dot{A}_{jn} G_{ij} + [1 + \langle F' \rangle^2 \xi_L - 2 \langle F' \rangle U_i g_i] \ddot{A}_{nm} + 2 \langle F' \rangle \ddot{A}^{10}_{nm} - \ddot{W}_{inm} g_i + O(P_L^3) \} \tag{78}$$

Lagrangian bias

Cumulants

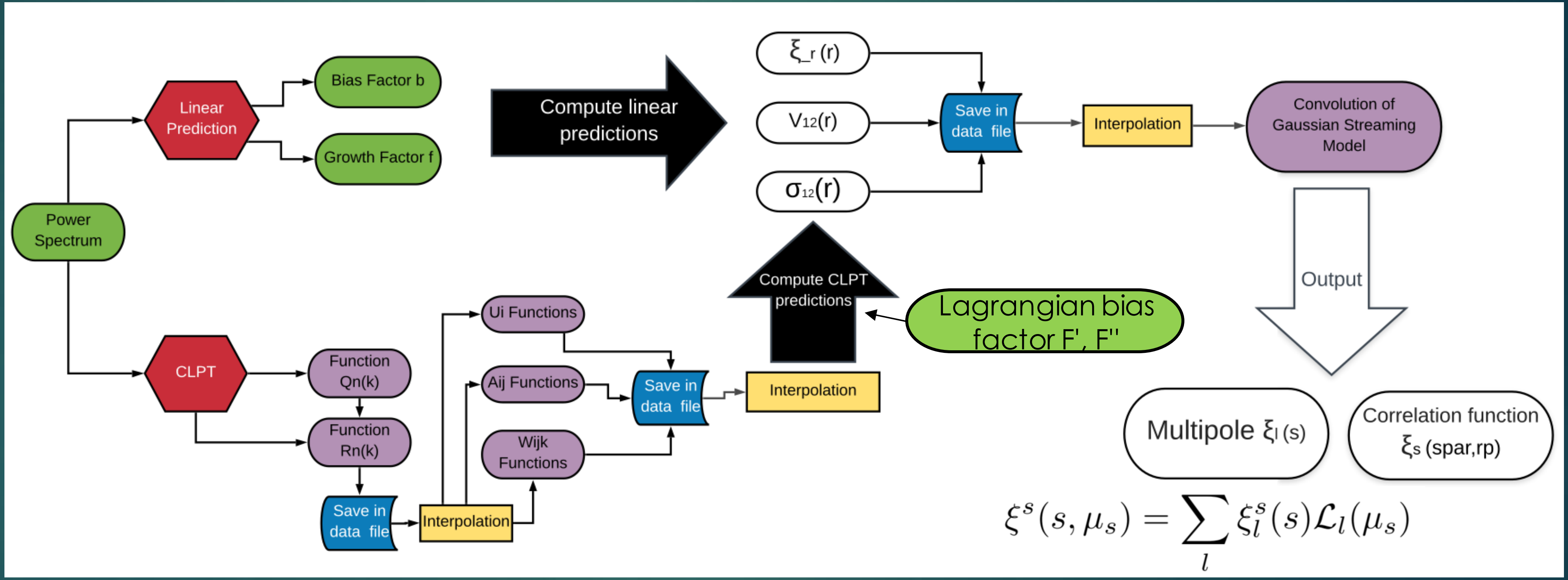
$$\langle \delta_1^m \delta_2^n \Delta_{i_1} \dots \Delta_{i_r} \rangle$$

Quasi linear regime
Cut at order 2

My work

I Wrote a C code of the GSM with linear and CLPT predictions

Cosmo
Ω_m, h, σ_8



My work

$$M_0 = \frac{1}{(2\pi)^{3/2}|A|^{1/2}} \; e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T\mathbf{A}^{-1}(\boldsymbol{r}-\boldsymbol{q})} \times \Big\{1 + \langle F'\rangle^2 \xi_R - 2\langle F'\rangle U_i g_i + \frac{1}{2}\langle F''\rangle^2 \xi_R - 2\langle F'\rangle\langle F''\rangle \xi_R U_i g_i$$
$$- [\langle F''\rangle + \langle F'\rangle^2] U_i U_j G_{ij} + \frac{1}{6} W_{ijk}\Gamma_{ijk} - \langle F'\rangle A_{ij}^{10} G_{ij} - \langle F''\rangle U_i^{20} g_i - \langle F'\rangle^2 U_i^{11} g_i + O(P_L^3)\Big\} \tag{76}$$

$$M_{1,n} = \frac{f^2}{(2\pi)^{3/2}|A|^{1/2}} \; e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T\mathbf{A}^{-1}(\boldsymbol{r}-\boldsymbol{q})} \times \Big\{2\langle F'\rangle \dot{U}_n - g_i\dot{A}_{in} + \langle F''\rangle \dot{U}_n^{20} + \langle F'\rangle^2 \dot{U}^{11_n} + 2\langle F'\rangle\langle F''\rangle \xi_L \dot{U}_n$$
$$- 2\langle F'\rangle g_i \dot{A}_{in}^{10} - \frac{1}{2} G_{ij}\dot{W}_{ijn} - 2[\langle F''\rangle + \langle F'\rangle^2] g_i U_i \dot{U}_n - \langle F'\rangle^2 \xi_L g_i \dot{A}_{in} - 2\langle F'\rangle G_{ij} U_i \dot{A}_{in} + O(P_L^3)\Big\} \tag{77}$$

$$M_{2,nm} = \frac{f^2}{(2\pi)^{3/2}|A|^{1/2}} \; e^{-\frac{1}{2}(\boldsymbol{r}-\boldsymbol{q})^T\mathbf{A}^{-1}(\boldsymbol{r}-\boldsymbol{q})} \times \{2[\langle F'\rangle^2 + \langle F''\rangle]\dot{U}_n\dot{U}_m - 2\langle F'\rangle(\dot{A}_{in} g_i \dot{U}_m + \dot{A}_{im} g_i \dot{U}_n)$$
$$- \dot{A}_{im}\dot{A}_{jn} G_{ij} + [1 + \langle F'\rangle^2 \xi_L - 2\langle F'\rangle U_i g_i]\ddot{A}_{nm} + 2\langle F'\rangle \ddot{A}_{nm}^{10} - \ddot{W}_{inm} g_i + O(P_L^3)\} \tag{78}$$

My work

Finaly...

$$U_i = U_i^{(1)} + U_i^{(3)} + \cdots\ , \quad U_i^{20} = U_i^{20(2)} + \cdots\ , \quad U_i^{11} = U_i^{11(2)} + \cdots\ ,$$
$$A_{ij} = A_{ij}^{(11)} + A_{ij}^{(22)} + A_{ij}^{(13)} + A_{ij}^{(31)} + \cdots\ , \quad A_{ij}^{10} = A_{ij}^{10(12)} + A_{ij}^{10(21)} + \cdots$$
$$W_{ijk} = W_{ijk}^{(112)} + W_{ijk}^{(121)} + W_{ijk}^{(211)} + \cdots\ .$$

$$\dot U_n = \frac{\langle \delta_1 \dot\Delta_n\rangle}{f} = U_n^{(1)} + 3U_n^{(3)} + \cdots\ , \quad \dot U_n^{20} = \frac{\langle \delta_1^2 \dot\Delta_n\rangle}{f} = U_n^{20(2)} + \cdots\ , \quad \dot U_n^{11} = \frac{\langle \delta_1\delta_2 \dot\Delta_n\rangle}{f} = U_n^{11(2)} + \cdots$$
$$\dot A_{in} = \frac{\langle \Delta_i \dot\Delta_n\rangle}{f} = A_{in}^{(11)} + 3A_{in}^{(13)} + A_{in}^{(31)} + 2A_{in}^{(22)} + \cdots\ , \quad \dot A_{in}^{10} = \frac{\langle \delta_1\Delta_i \dot\Delta_n\rangle}{f} = 2A_{in}^{10(12)} + A_{in}^{10(21)} + \cdots$$
$$\dot W_{ijn} = \frac{\langle \delta_1\Delta_i\Delta_j \dot\Delta_n\rangle}{f} = 2W_{ijn}^{(112)} + W_{ijn}^{(121)} + W_{ijn}^{(211)} + \cdots$$

$$U_i^{mn(p)} = \langle \delta_1^m \delta_2^n \Delta_i^{(p)}\rangle_c\ , \quad A_{ij}^{mn(pq)} = \langle \delta_1^m \delta_2^n \Delta_i^{(p)}\Delta_j^{(q)}\rangle_c$$
$$W_{ijk}^{mn(pqr)} = \langle \delta_1^m \delta_2^n \Delta_i^{(p)}\Delta_j^{(q)}\Delta_k^{(r)}\rangle_c\ ,$$

$$\ddot A_{nm} = \frac{\langle \dot\Delta_n \dot\Delta_m\rangle}{f^2} = A_{nm}^{(11)} + 3A_{nm}^{(13)} + 3A_{nm}^{(31)} + 4A_{nm}^{(22)}\ ,$$
$$\ddot A_{10,nm} = \frac{\langle \delta_1 \dot\Delta_n \dot\Delta_m\rangle}{f^2} = 2A_{nm}^{10(12)} + 2A_{nm}^{10(21)}\ ,$$
$$\ddot W_{inm} = \frac{\langle \delta_1\Delta_i \dot\Delta_n \dot\Delta_m\rangle}{f^2} = 2W_{inm}^{(112)} + 2W_{inm}^{(121)} + W_{inm}^{(211)}\ .$$

$$R_n(k) = \frac{k^3}{4\pi^2} P_L(k) \int_0^\infty dr\ P_L(kr)\widetilde R_n(r)$$
$$Q_n(k) = \frac{k^3}{4\pi^2} \int_0^\infty dr\ P_L(kr) \int_{-1}^1 dx\ P_L(k\sqrt{y})Q_n(r,x)\ ,$$

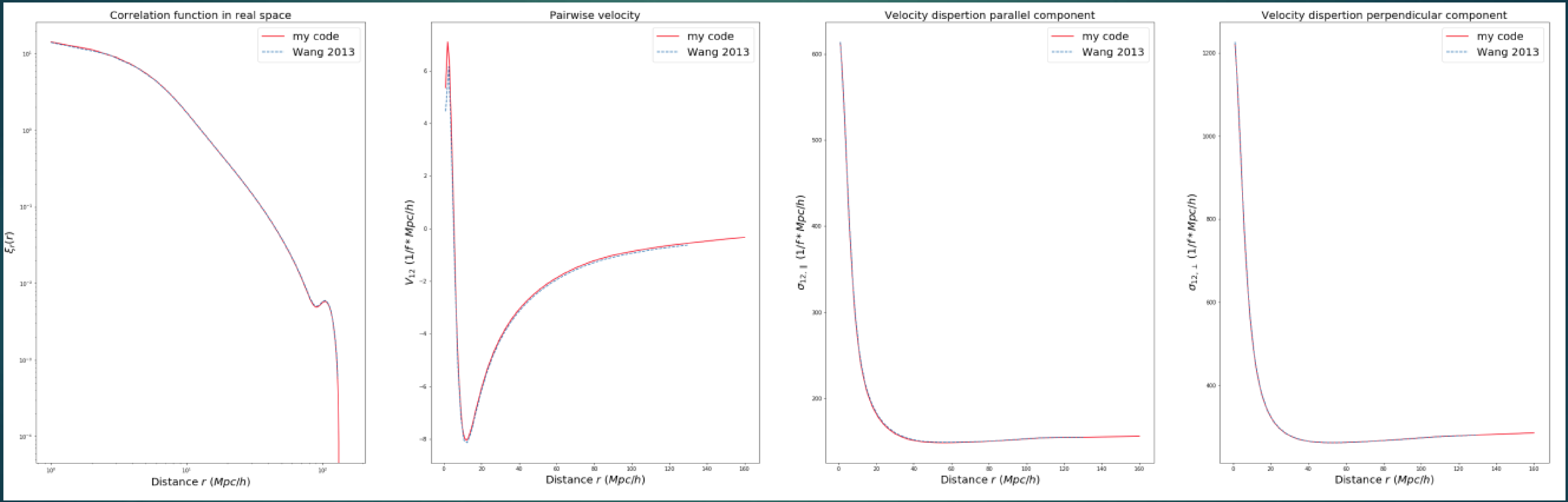
$$Q_1 = \frac{r^2(1-x^2)^2}{y^2}, \quad Q_2 = \frac{(1-x^2)rx(1-rx)}{y^2},$$
$$Q_5 = \frac{rx(1-x^2)}{y}, \quad Q_8 = \frac{r^2(1-x^2)}{y},$$
$$\widetilde R_1(r) = \int_{-1}^{+1} dx\ \frac{r^2(1-x^2)^2}{1+r^2-2rx}$$
$$\widetilde R_2(r) = \int_{-1}^{+1} dx\ \frac{(1-x^2)rx(1-rx)}{1+r^2-2rx}$$

$$\xi_L(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ k^2 P_L(k) j_0(kq)$$
$$V_1^{(112)}(q) = \frac{1}{2\pi^2}\int_0^\infty \frac{dk}{k} \left(-\frac{3}{7}\right) R_1(k) j_1(kq)$$
$$V_3^{(112)}(q) = \frac{1}{2\pi^2}\int_0^\infty \frac{dk}{k} \left(-\frac{3}{7}\right) Q_1(k) j_1(kq)$$
$$S^{(112)}(q) = \frac{1}{2\pi^2}\int_0^\infty \frac{dk}{k}\ \frac{3}{7}\left[2R_1(k) + 4R_2(k) + Q_1(k) + 2Q_2(k)\right]\frac{j_2(kq)}{kq}$$
$$T^{(112)}(q) = \frac{1}{2\pi^2}\int_0^\infty \frac{dk}{k} \left(-\frac{3}{7}\right) \times \left[2R_1 + 4R_2 + Q_1 + 2Q_2\right] j_3(kq)$$
$$U^{(1)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ k\ (-1) P_L(k) j_1(kq)$$
$$U^{(3)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ k \left(-\frac{5}{21}\right) R_1(k) j_1(kq)$$
$$U_{20}^{(2)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ k \left(-\frac{3}{7}\right) Q_8(k) j_1(kq)$$
$$U_{11}^{(2)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ k \left(-\frac{6}{7}\right) [R_1(k) + R_2(k)] j_1(kq)$$

$$X_{10}^{(12)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ \frac{1}{14}\Big\{2[R_1(k) - R_2(k)] + 3R_1(k)j_0(kq) - 3[3R_1(k) + 4R_2(k) + 2Q_5(k)]\frac{j_1(kq)}{kq}\Big\}$$
$$Y_{10}^{(12)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk \left(-\frac{3}{14}\right)[3R_1(k) + 4R_2(k) + 2Q_5(k)] \times \left[j_0(kq) - 3\frac{j_1(kq)}{kq}\right]$$
$$X^{(11)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ P_L(k)\left[\frac{2}{3} - 2\frac{j_1(kq)}{kq}\right]$$
$$X^{(22)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ \frac{9}{98}Q_1(k)\left[\frac{2}{3} - 2\frac{j_1(kq)}{kq}\right]$$
$$X^{(13)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ \frac{5}{21}R_1(k)\left[\frac{2}{3} - 2\frac{j_1(kq)}{kq}\right]$$
$$Y^{(11)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ P_L(k)\left[-2j_0(kq) + 6\frac{j_1(kq)}{kq}\right]$$
$$Y^{(22)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ \frac{9}{98}Q_1(k)\left[-2j_0(kq) + 6\frac{j_1(kq)}{kq}\right]$$
$$Y^{(13)}(q) = \frac{1}{2\pi^2}\int_0^\infty dk\ \frac{5}{21}R_1(k)\left[-2j_0(kq) + 6\frac{j_1(kq)}{kq}\right]$$

Code comparison results

CLPT moments comparison with code from Reid et al. 2011

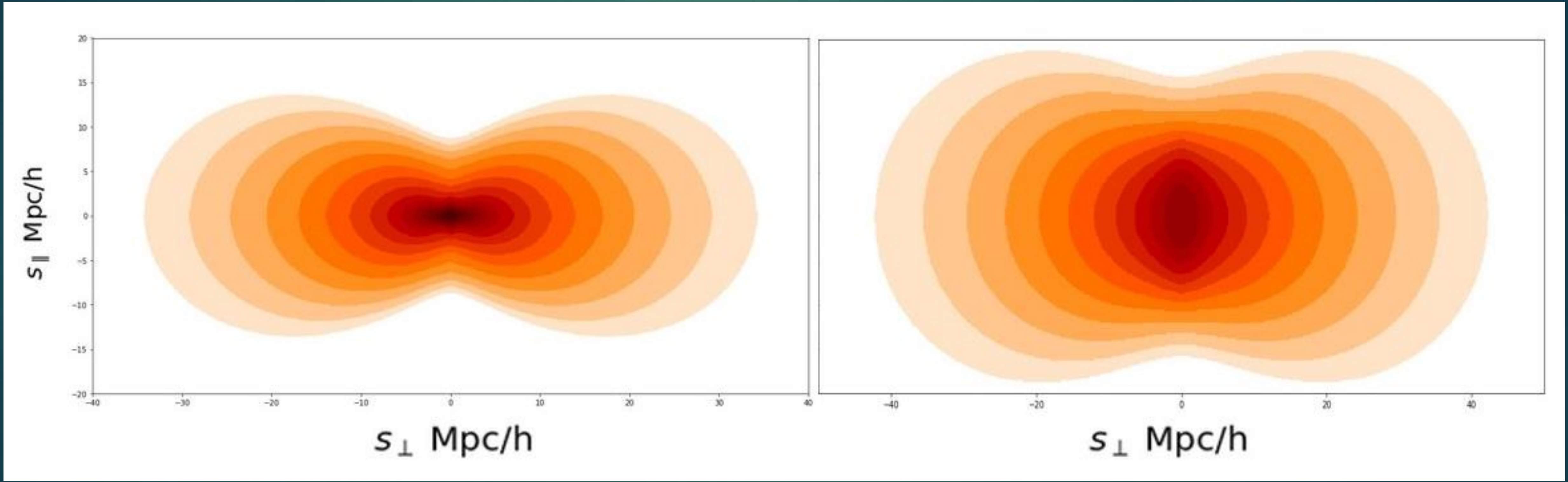


Perfect agreement when taking same inputs

Code predictions

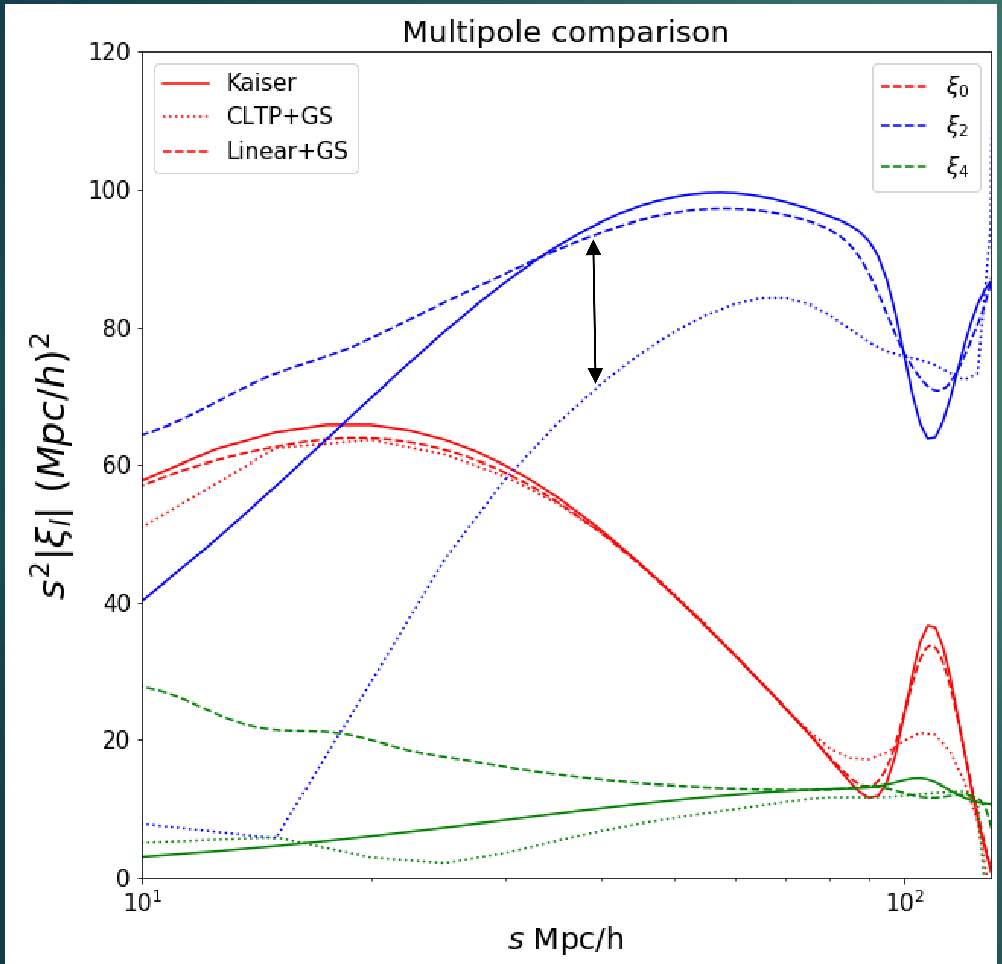
CLPT two-point correlation function contours

Linear GSM CLPT GSM

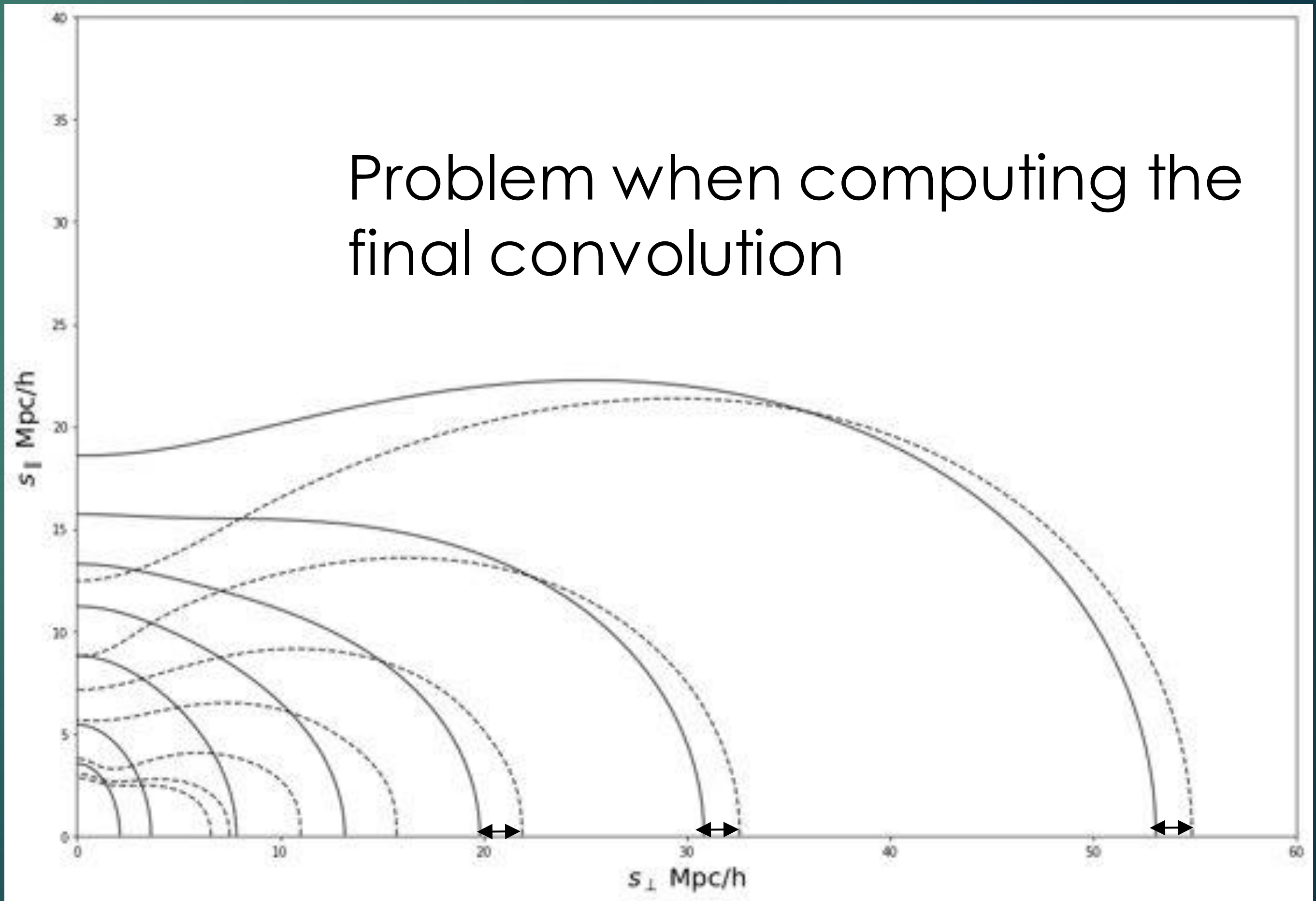


Code predictions

Multipole moments comparison for different predictions



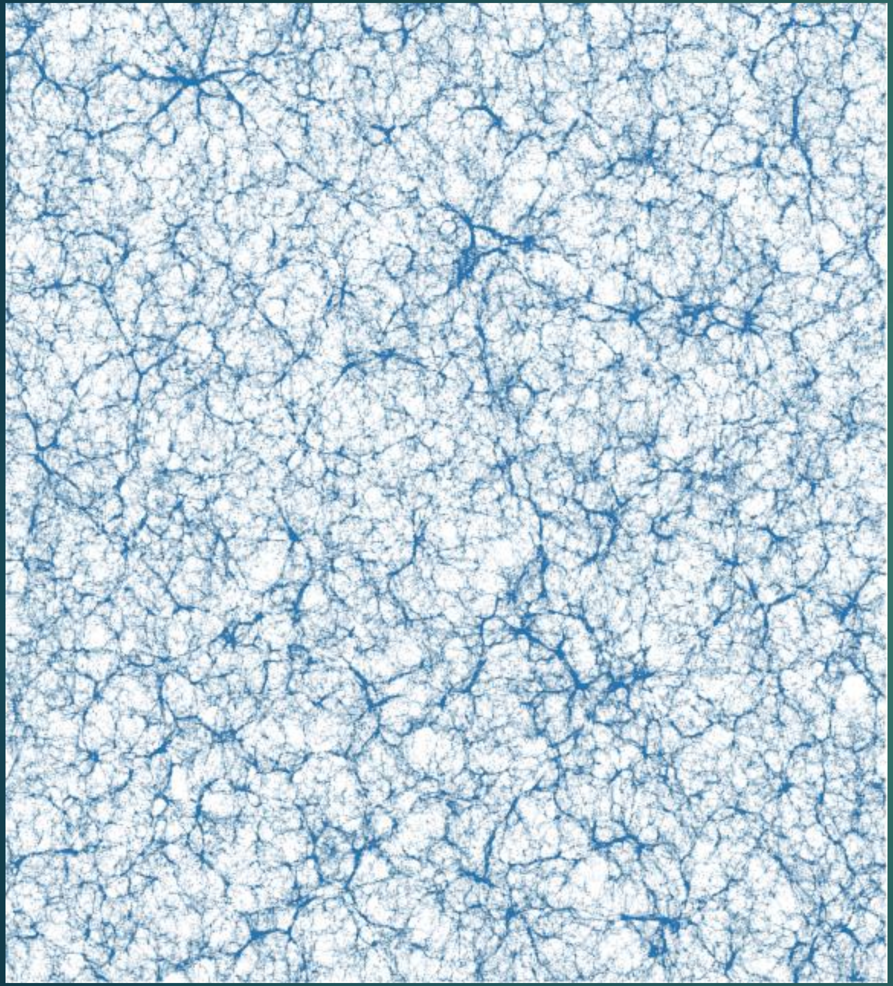
2PCF comparison from linear GSM (dasehd line) and CLPT GSM (solid line)



Compare with simulation

Simulation UNITS (Feng et al. 216)

$\Omega_m = 0.3089$, $h \equiv H_0/100 = 0.6774$ and $\sigma_8 = 0.8147$

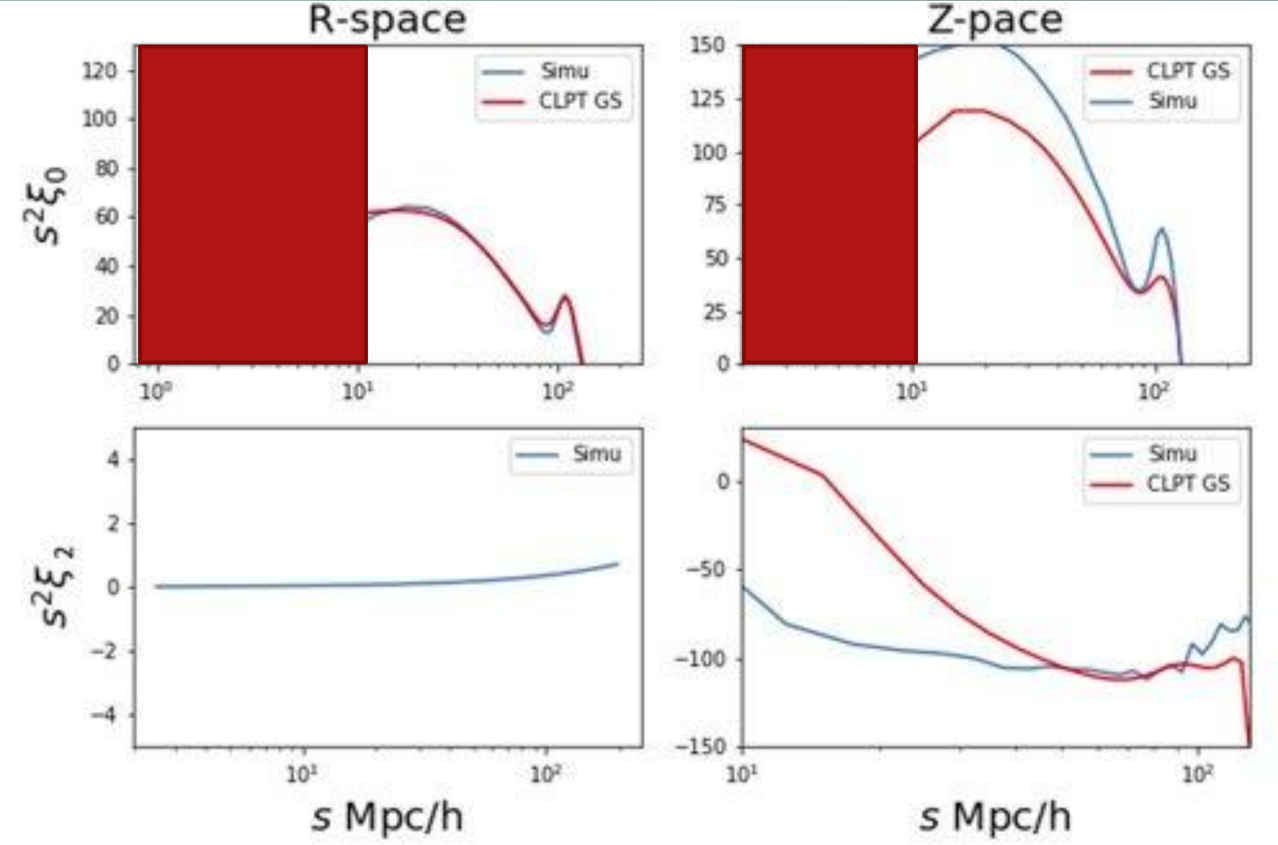


Box size 1Gpc at z=0

Bias fitting

F' = 0.48

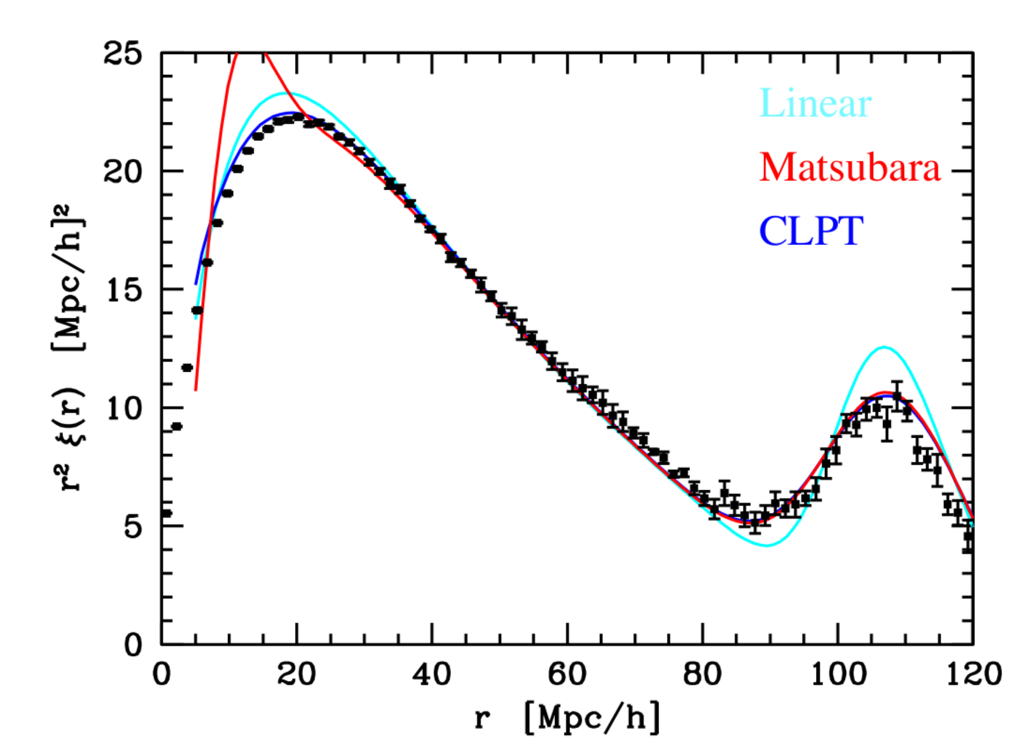
F''=0.05

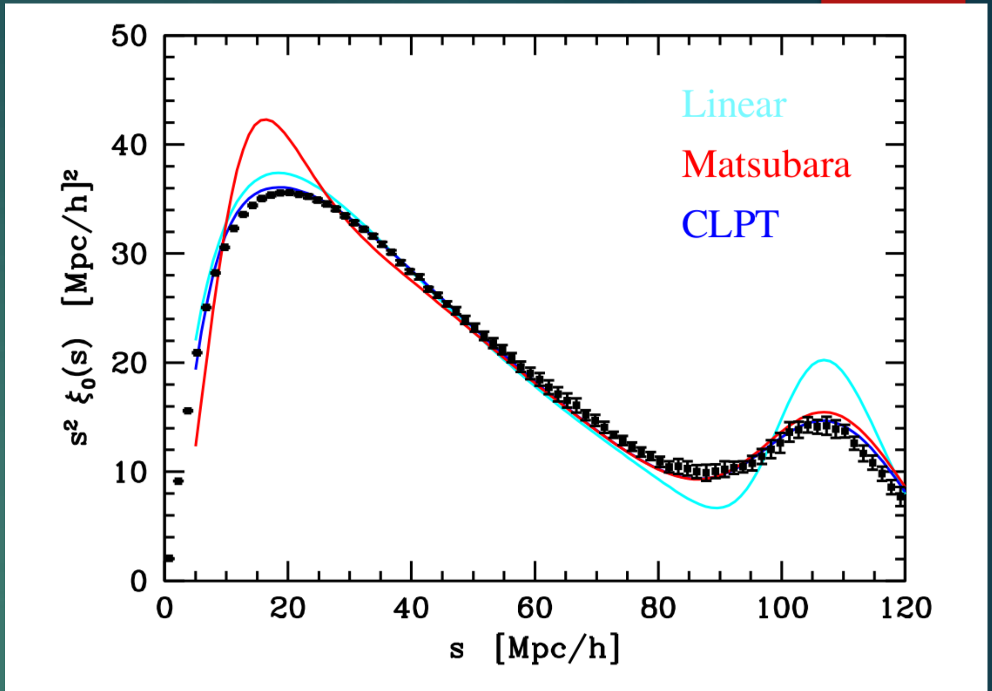


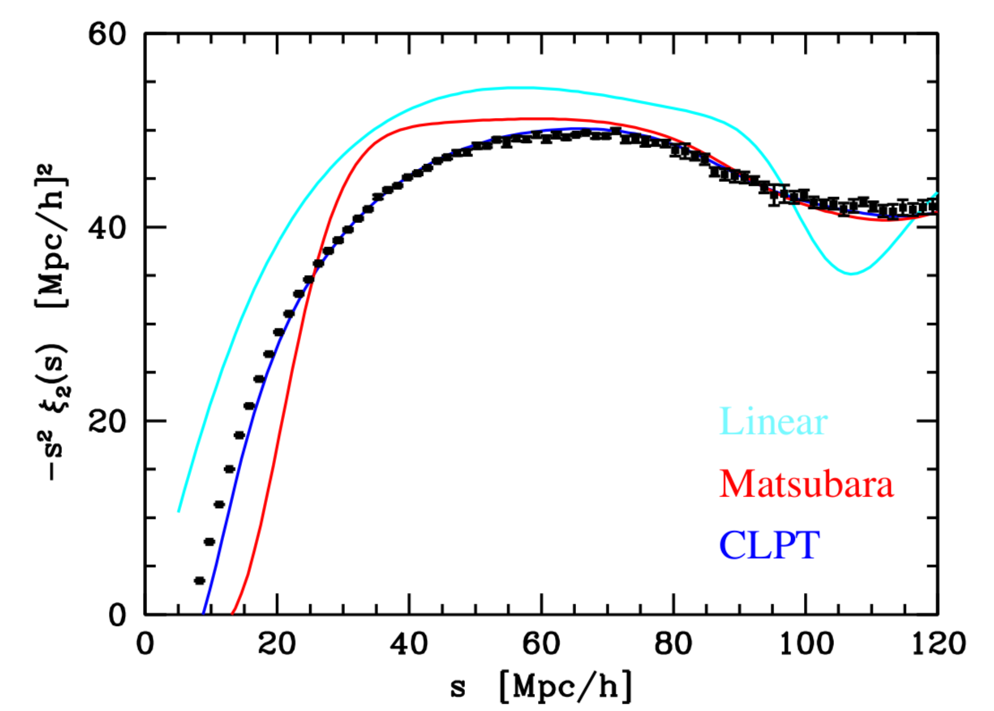
Landy-Szalay estimator

$$\xi(r) = \frac{DD(r) - 2DR(r) + RR(r)}{RR(r)}$$

Expected results from CLPT







The GS/CLPT model allows reproducing RSD signal down to 20 Mpc/h (quasilinear regime) within 1%

White 2012

Conclusion

- RSD is crucial to test gravity (on large scales) and cosmic acceleration

- Need reduce systematics from RSD non-linear modelling for precision cosmology: statistical errors under 1% for future redshift surveys such as EUCLID or DESI

- GS/CLPT is a robust RSD model that seems to meet the precision requirements for scales above 20 Mpc/h

- Still need to optimise the model with more detailed comparisons to with simulations

Thanks !