Peculiar velocity

$\vec{v} = \vec{v}_H + \vec{v}_p$. Hubble expansion $v_H = Hd$, peculiar velocity $\vec{v}_p = \vec{u}$

redshift $1+z = \lambda_{obs} / \lambda_{rest}$ what about objects at $z > 1$?

Doppler effect $\rightarrow 1 \pm v/c$ peculiar velocity . yes Doppler , but separation is arbitrary

$\Rightarrow$ only radial component . tangential component : parallax , transverse Doppler

Linear theory

let $\vec{v}_p = -\nabla U$ velocity potential U (rotation free)

$\theta = -\frac{1}{a}\vec{\nabla}\cdot\vec{v}_p = \frac{1}{a}\Delta U = \dot{\delta} = Hf\delta$. $U = Hf\Delta^{-1}\delta \rightarrow -\frac{Hf}{k^2}\delta_k$. $\vec{v}_k = i\vec{k}\frac{Hf}{k^2}\delta_k$

similar to the matter power spectrum . velocity correlation $\langle v_i(\vec{x}) v_j(\vec{x}+\vec{r})\rangle$

Redshift-Space distortion

redshift z measurement $\rightarrow$ radial distance comoving $s := \int_0^z \frac{dz'}{H}$ but also with v_p

$1+z := (1+\bar{z})(1+\delta z)$ or $z = \bar{z} + (1+\bar{z})\delta z$ $r := \int_0^{\bar{z}} \frac{dz'}{H}$. $d = \frac{r}{1+\bar{z}}$

$\delta z \simeq v_p$ at 1st order . but other relativistic effects.

$\Rightarrow s \simeq r + \frac{1+\bar{z}}{H}\delta z =: r + V$. $V := \frac{v_p}{H} = i\vec{k}\cdot\hat{n}\frac{f}{k^2}\delta_k = -f\frac{\partial}{\partial r}\Delta^{-1}\delta$

radial distance changes due to v_p . infall toward overdense region

Impact on Observations (RSD)

galaxy # density to compute 2pt correlation, but $n_g(r) \neq n_g(s)$ in observation due to RSD

radial position : r real-space, s redshift-space

angular position : same in both, but in fact gravitational lensing

but total # is conserved : $n_g(s)\,d^3s = n_g(r)\,d^3r$ $\quad dV_r = d^3r = r^2 dr\, d\Omega$

$\Rightarrow n_g(s) = n_g(r)\left|\frac{d^3r}{d^3s}\right| \leftarrow$ Jacobian, $s = r + v$, $\frac{ds}{dr} = 1 + \frac{dv}{dr}$ $\quad s^2 = r^2\left(1+\frac{1}{r}v\right)^2 \doteq r^2\left(1+\frac{2}{r}v\right)$

$n_g(s) = n_g(r) + \left.\frac{dn_g}{dr}\right| \cdot v + \cdots$

$\therefore\ 1+\delta_s = (1+\delta_g)\left(1+\frac{d\ln\bar{n}_g}{dr}\cdot v\right)^{-1}\left(1+\frac{2}{r}v\right)^{-1}\left(1+\frac{dv}{dr}\right)^{-1}$

$\Rightarrow\ \delta_s = \delta_g - \left(\frac{d}{dr} + \frac{\alpha}{r}\right)v$, $\quad \alpha \doteq 2 + \frac{d\ln\bar{n}_g}{d\ln r}$ $\quad$ at large r $\quad \underline{\delta_s = \delta_g - \frac{d}{dr}v}$

$v_k = i\vec{k}\cdot\hat{n}\,\frac{f}{k^2}\delta_k$, $\quad \frac{d}{dr}v = -f\mu_k^2\delta_k$, $\quad \mu_k \doteq \hat{k}\cdot\hat{n}$

Galaxy bias $\quad \delta_g = b\cdot\delta_m$, $\quad b$: constant $\sim 1-2$.

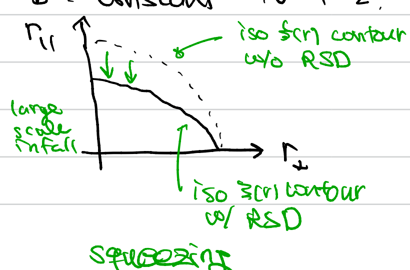
1987 by Kaiser $\quad$ MG sensitive

$\therefore\ P_s(k,\mu_k) = (b + f\mu_k^2)^2 P_m(k)$

RSD vanish at transverse direction

but enhanced along the LOS

$\Rightarrow$ anisotropy



1pt statistics

$\langle\rho_m\rangle = \bar{\rho}_m(t) \Rightarrow \Omega_m$

$\langle n_g\rangle = \bar{n}_g(t)$. $\quad P(k)$, Ω_m

$\cdots$