Measuring neutrino properties through relative flows

arXiv:1311.3422++

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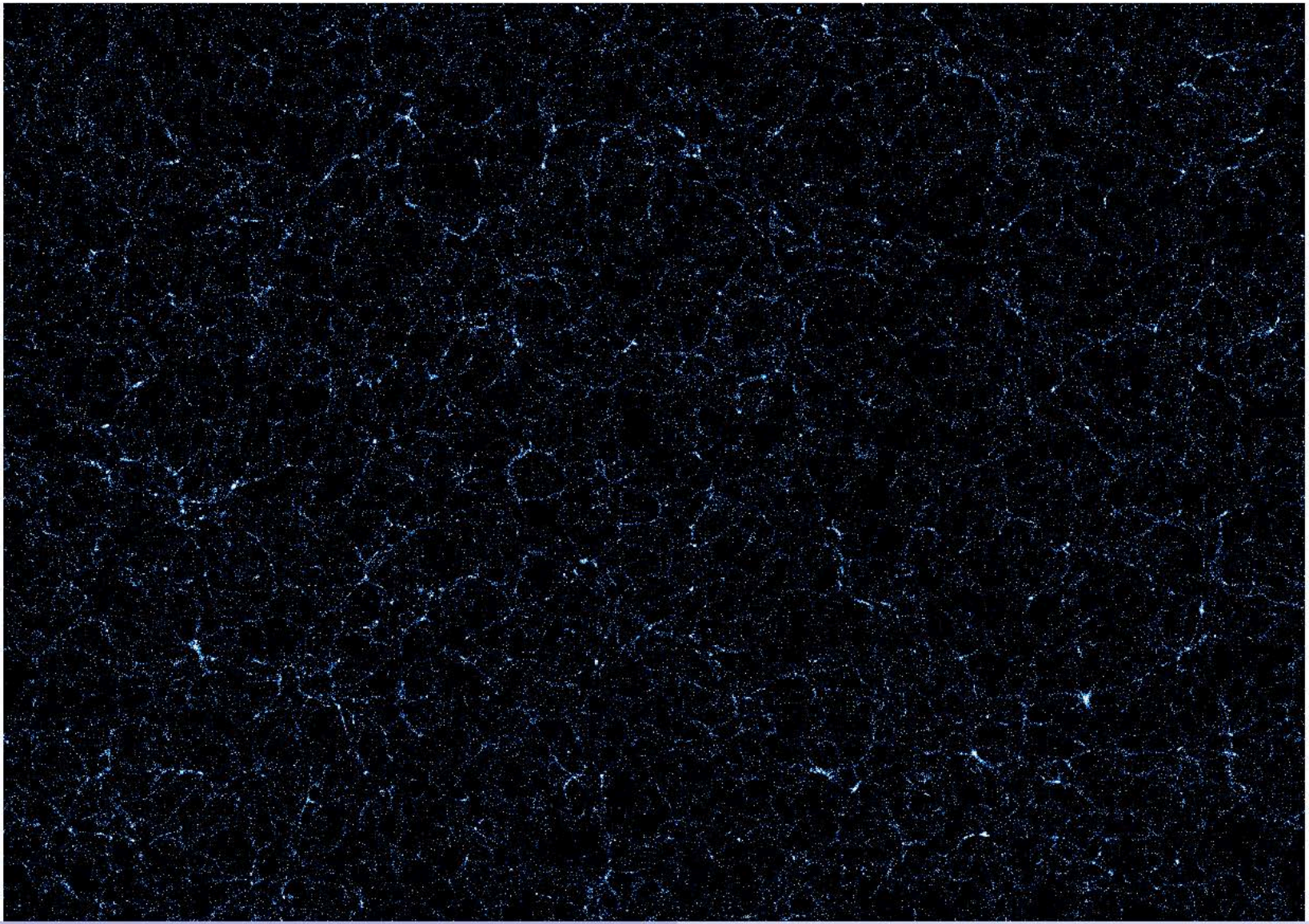
Overview

- Probe of neutrino masses, hierarchy, Majorana/Dirac
- Tseliakhovich-Hirata Effect: neutrino-CDM bulk flows
- Wakes
- Cross-correlation dipoles
- Observational forecast
- Conclusions

LSS probes of neutrino mass

- neutrinos impact power spectrum at $\sim$ % level
- modest scale dependence
- degenerate with $\sim$ % k-dependent bias
- potentially measurable through lensing – potential challenge from baryon feedback: $\Omega_\nu \sim 0.001 \ll \Omega_b$.
- mass hierarchy, Dirac-Majorana

CDM



ν

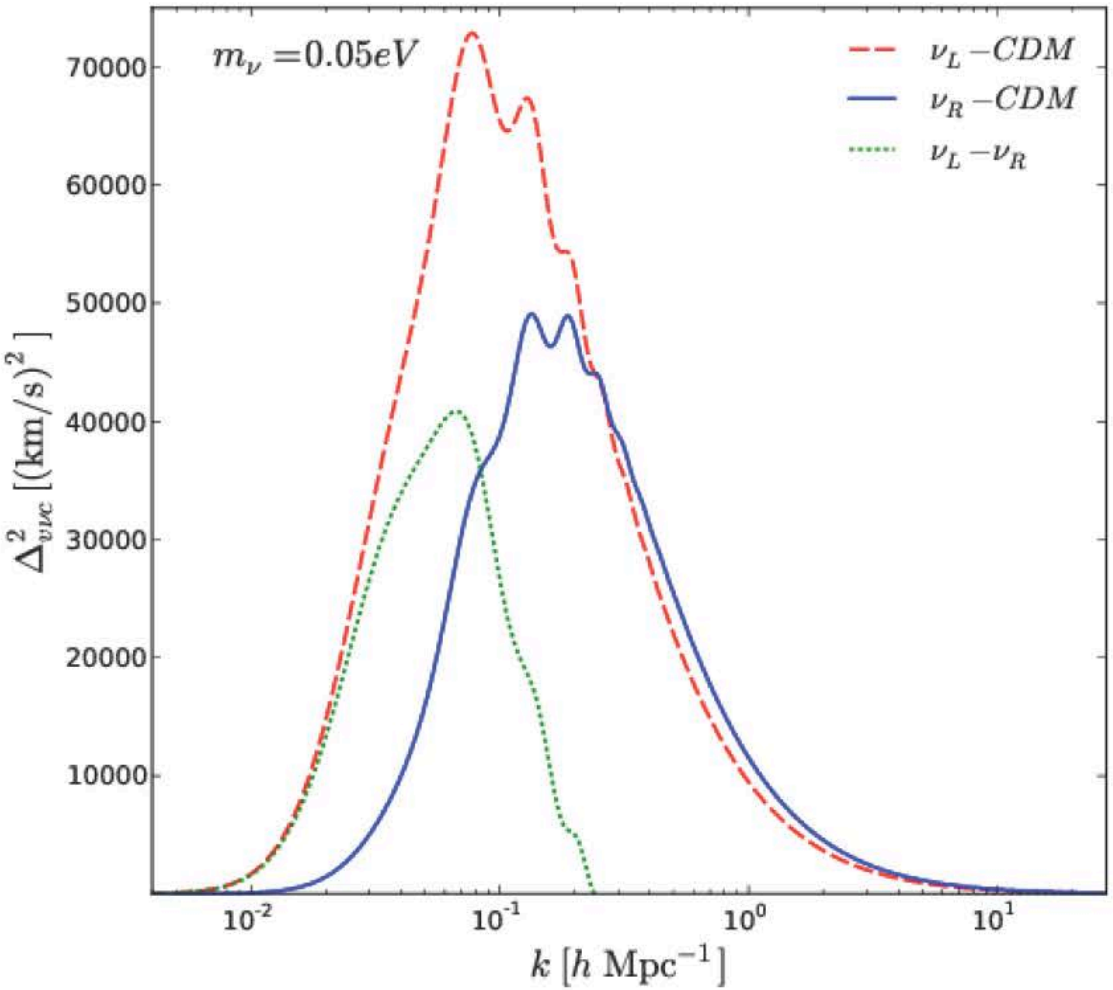
Tseliakhovich-Hirata Effect

- Tseliakhovich and Hirata (2010) realized that baryons and dark matter develop non-perturbative relative velocity flows after recombination.
- Analogous effect for neutrino-dark matter flow

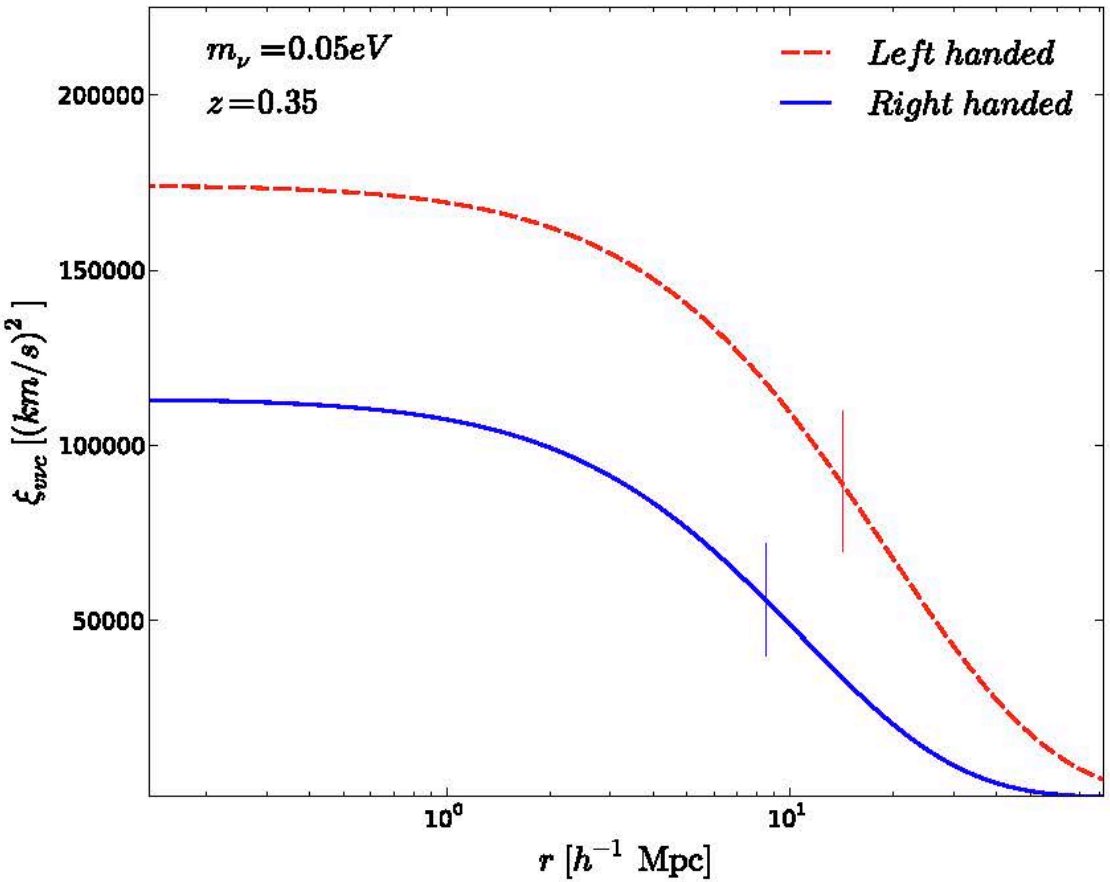
CDM-ν flows

- linear theory predicts velocity of all fluids from density field
- $\delta_\nu = \delta_c \frac{T_\nu}{T_c}$
- $\vec{v}_\nu \sim \delta_\nu \dot{T}_\nu \frac{i\vec{k}}{k^2}$
- $\vec{v}_{c\nu} \sim \delta_g \frac{\dot{T}_c - \dot{T}_\nu}{T_c} \frac{i\vec{k}}{k^2}$
- use galaxy survey (e.g. SDSS) to predict $\delta_c, \delta_\nu, v_{c\nu}$
- predictable today at high S/N.

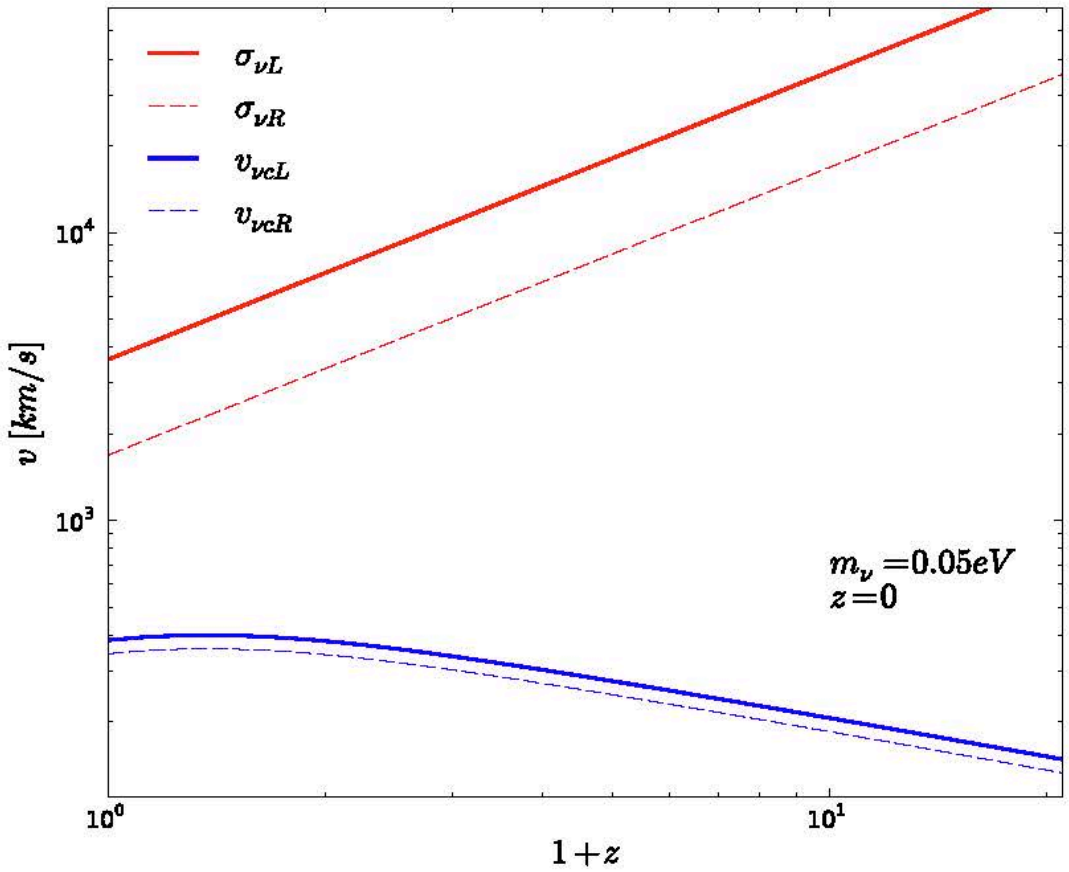
Flows


$m_\nu = 0.05eV$
$\nu_L - CDM$
$\nu_R - CDM$
$\nu_L - \nu_R$
70000
60000
50000
40000
30000
20000
10000
Δ^2_{vvc} [(km/s)^2]
10^{-2}
10^{-1}
10^{0}
10^{1}
k [h Mpc^{-1}]

Coherence


m_ν =0.05eV
z=0.35
Left handed
Right handed
200000
150000
100000
50000
ξ_{vvc} [(km/s)^2]
10^0
10^1
r [h^{-1} Mpc]

Mach


$\sigma_{\nu L}$
$\sigma_{\nu R}$
$v_{\nu cL}$
$v_{\nu cR}$
10^4
10^3
$v\ [km/s]$
$m_\nu = 0.05eV$
$z = 0$
10^0
10^1
$1+z$

Wakes

- each DM halo has downwind ν wake.
- potentially detectable with galaxy-galaxy lensing: search for dipole distortion
- or dipole of massive vs low mass galaxies.
- could use 21cm intensity mapping and tides (Pen et al 2012).

Textbook wake

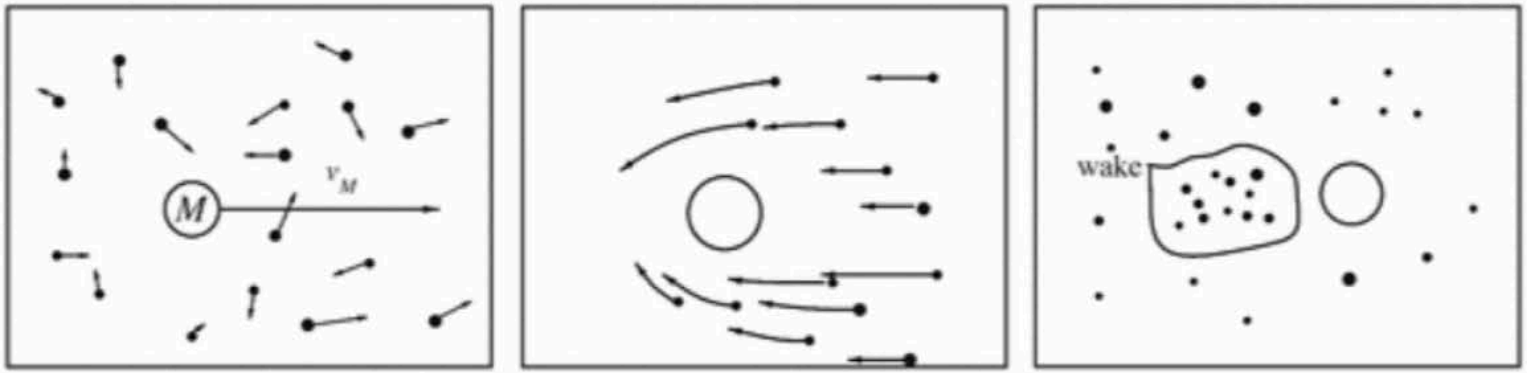
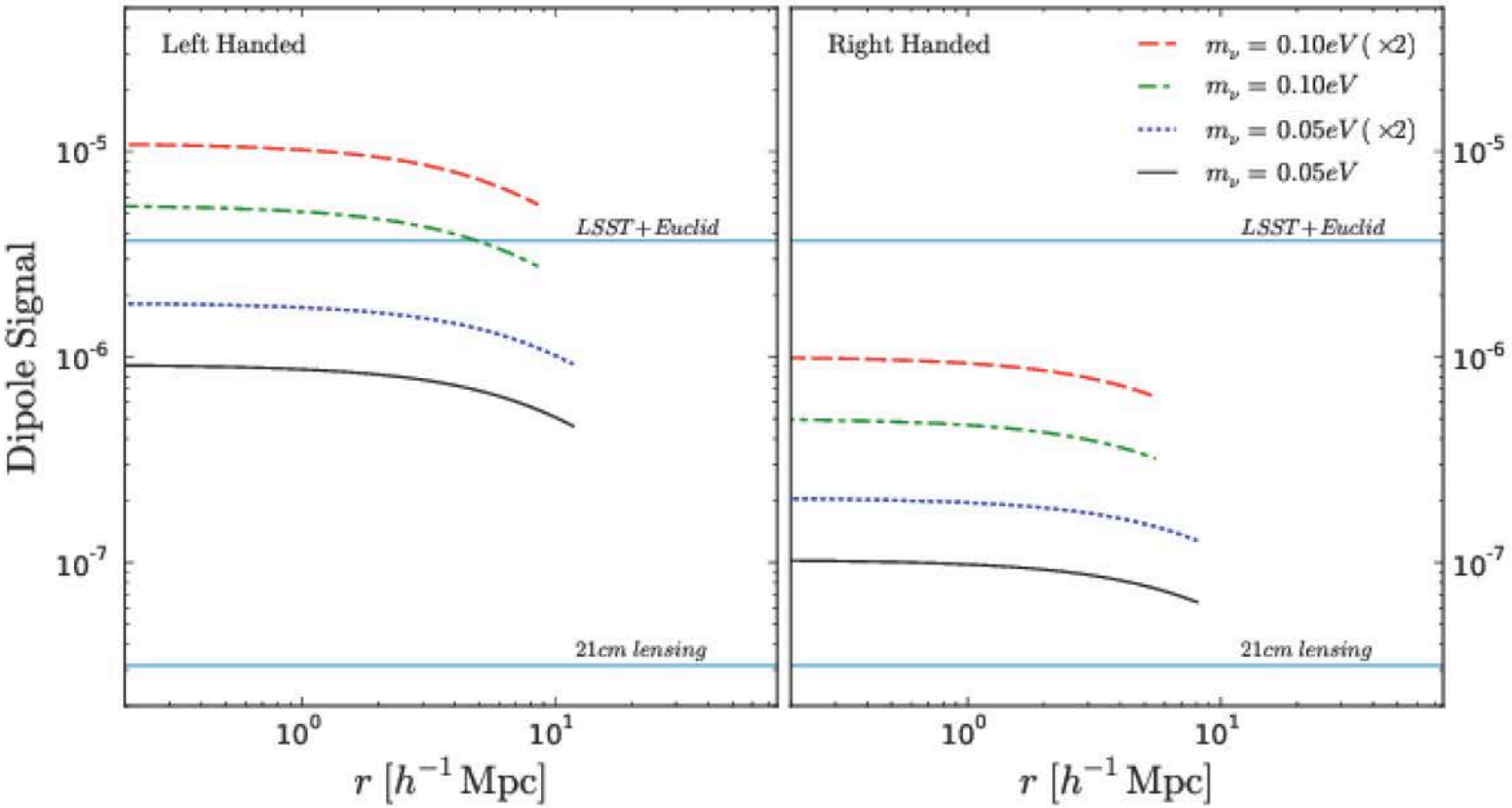


Fig. 7.1. Dynamical friction as a cartoon

Fellhauer, M.: *Dynamical Friction*. Lect. Notes Phys. **760**, 171–179 (2008)
DOI 10.1007/978-1-4020-8431-7_7

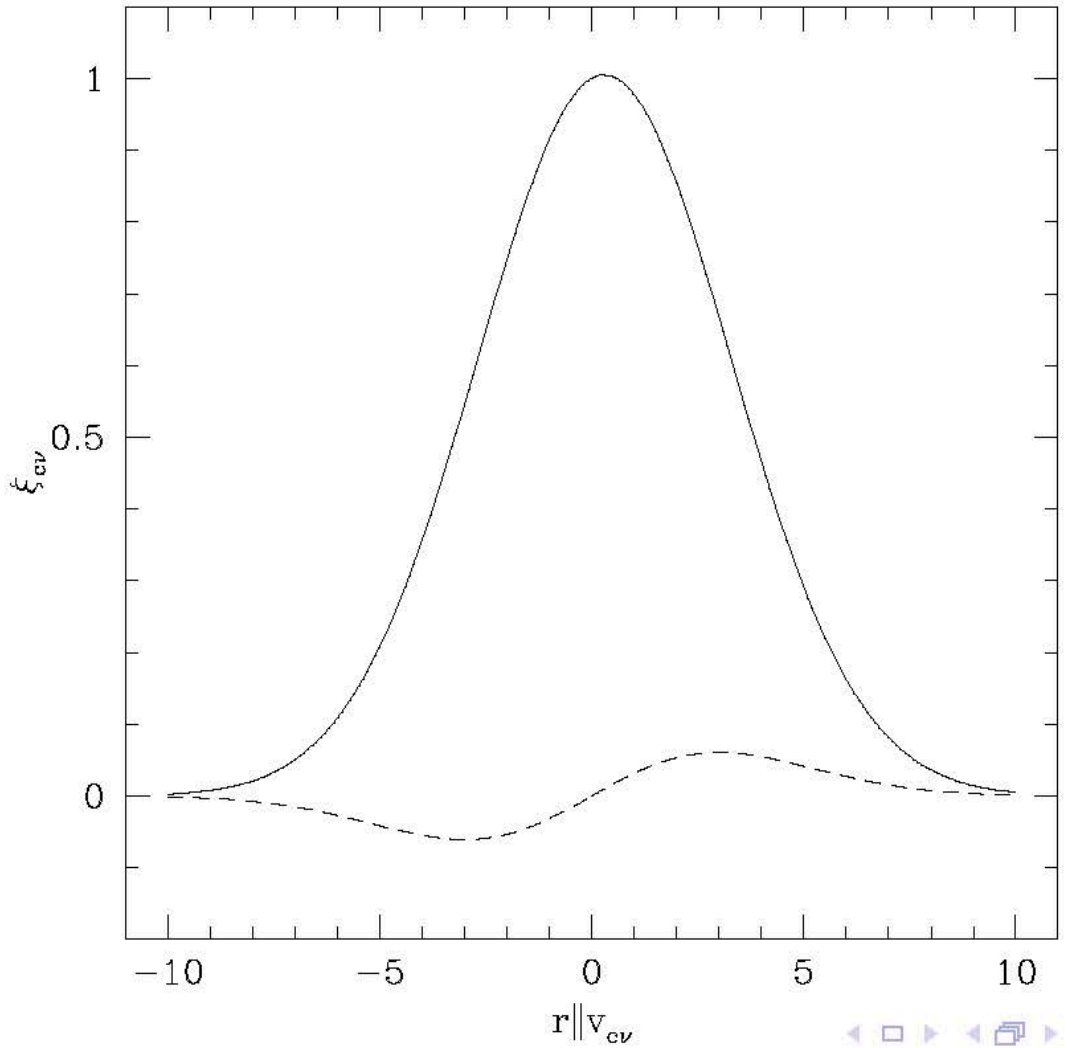
Wake lensing dipole (preliminary)



Correlation Dipole

- Bonvin et al, arXiv:1309.1321
- auto correlation functions always symmetric: $\xi(r) = \xi(-r)$ by definition.
- not true for cross correlation functions, $\xi_c(r) \neq \xi_c(-r)$
- needs a local direction to define r.
- Bonvin: $r_{||}$ along redshift direction
- New extension: $v_{c\nu}$ defines reference frame for r_v
- clean: no contamination from bias, no sample variance

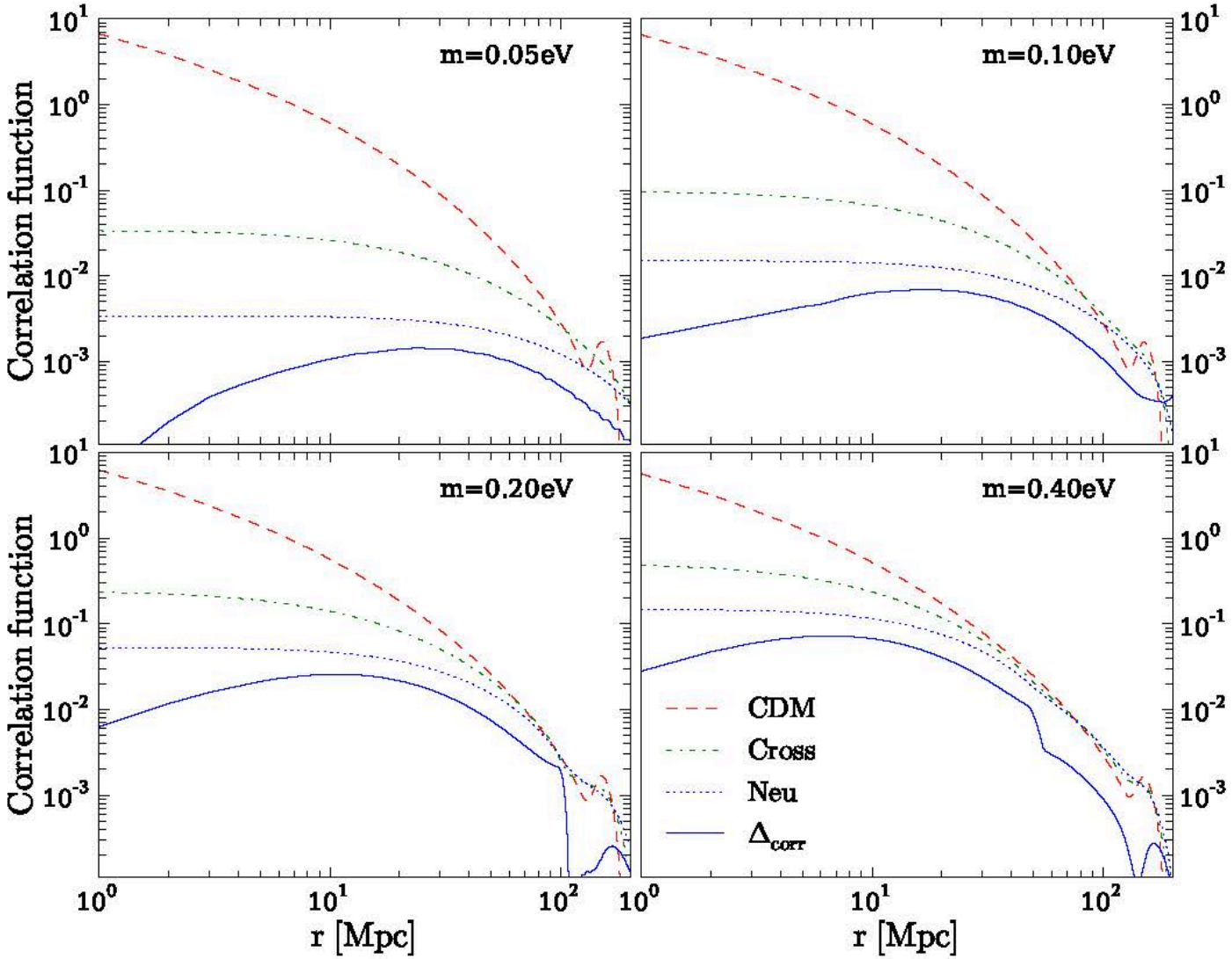
Dipole



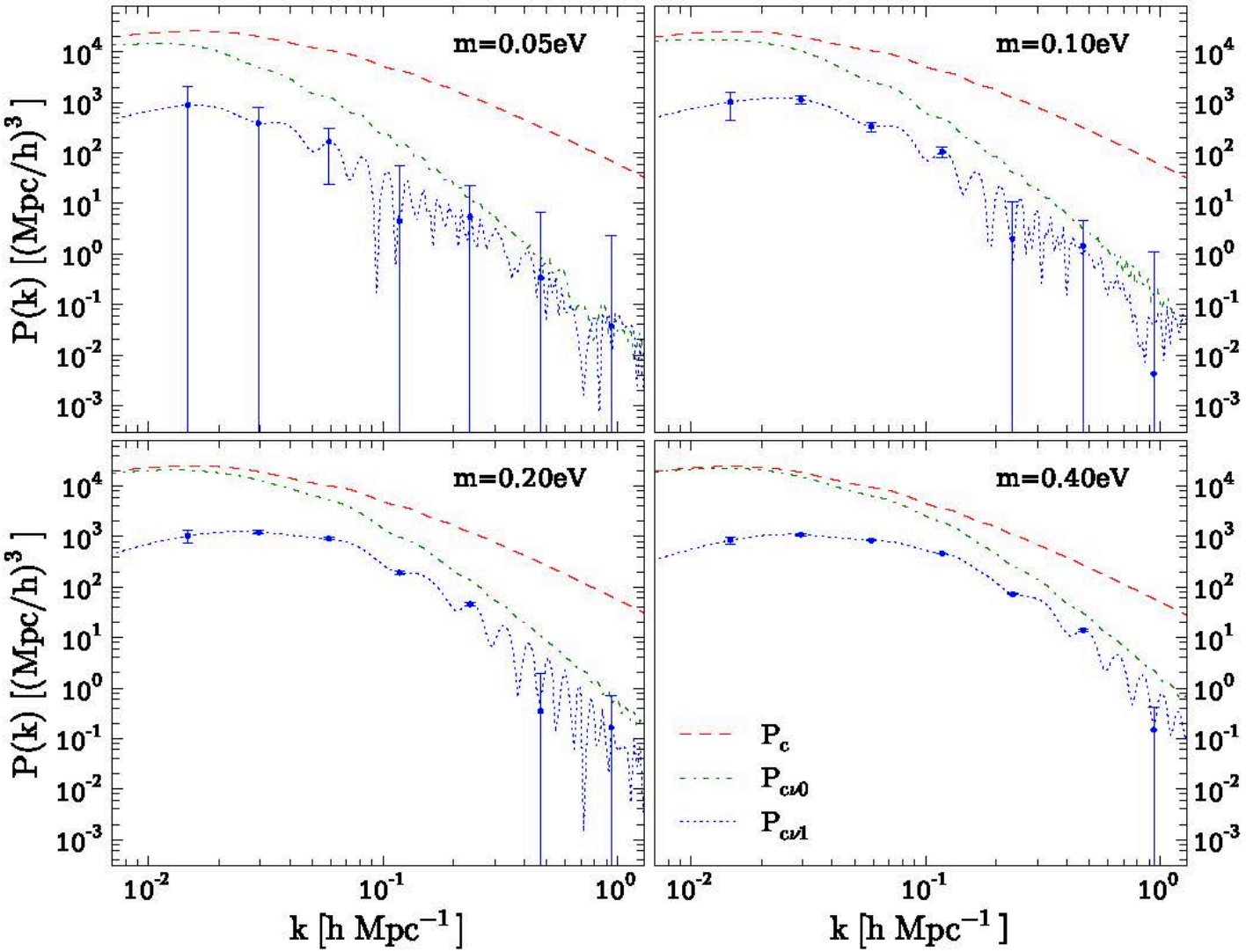
Observing Neutrinos?

- cross correlating two unobservable fields?
- cross correlate different galaxy types: $\delta_g^i = f_c^i \delta_c + f_\nu^i \delta_\nu$
- cross correlations: $\xi^{ij} = \langle \delta_g^i(x) \delta_g^j(x+r) \rangle \Big|_{r \| v_{c\nu}}$

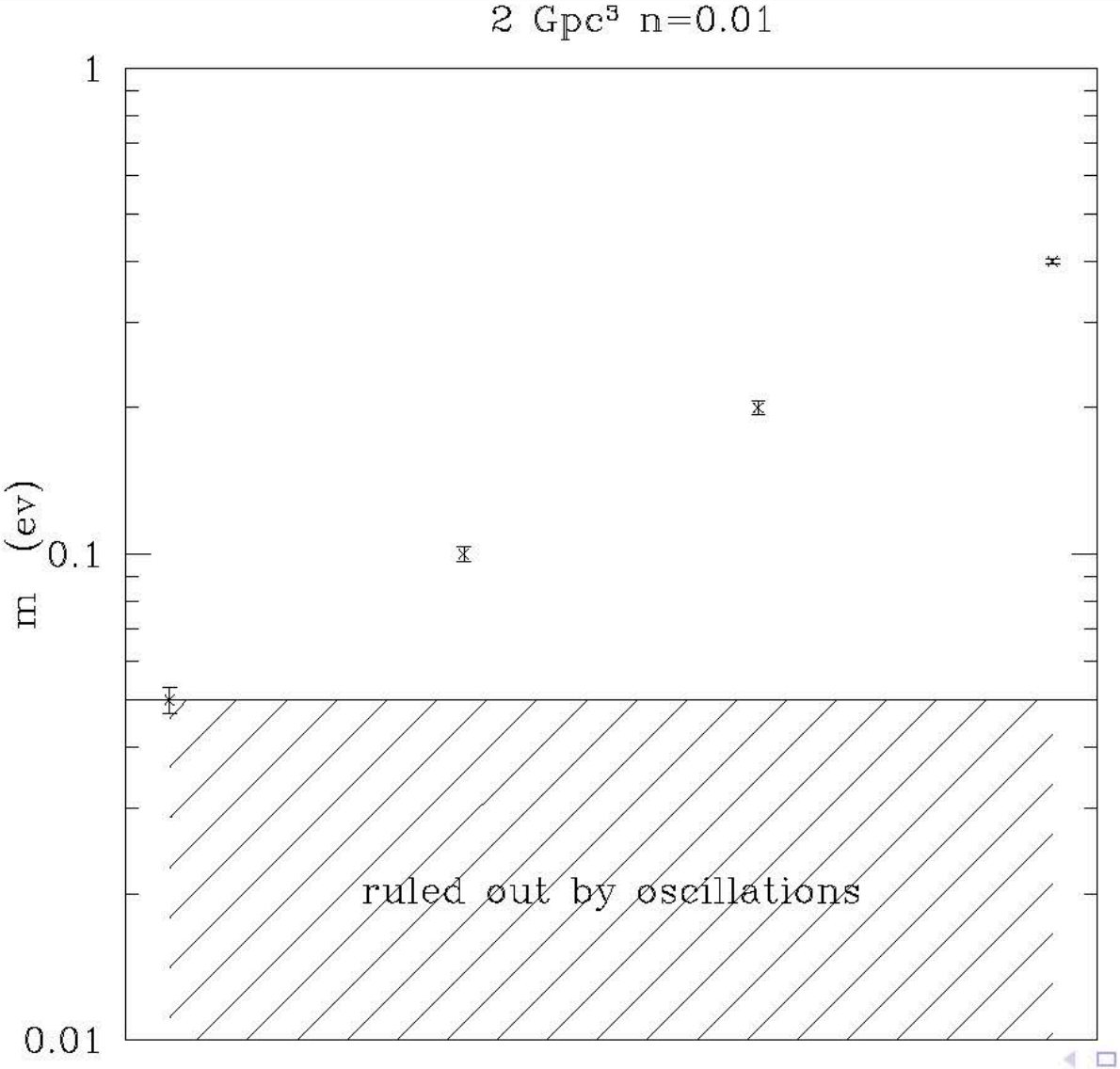
cross correlation



cross power



Fisher



Discussions

- flow direction depends on mass – use angles, not amplitudes to measure neutrino mass.
- detection may be clean and independent of bias.
- neutrino center-of-mass velocity comes from free streaming: hard to mimick by baryons.

Conclusions

- DM-ν dynamics very clean problem
- Bulk relative flow: TH effect
- leads to wakes, dipole
- signal depends on neutrino mass, not sum of mass: measure hierarchy
- possibility for detecting right handed Dirac cosmic background neutrinos