# Neutrino winds on the sky

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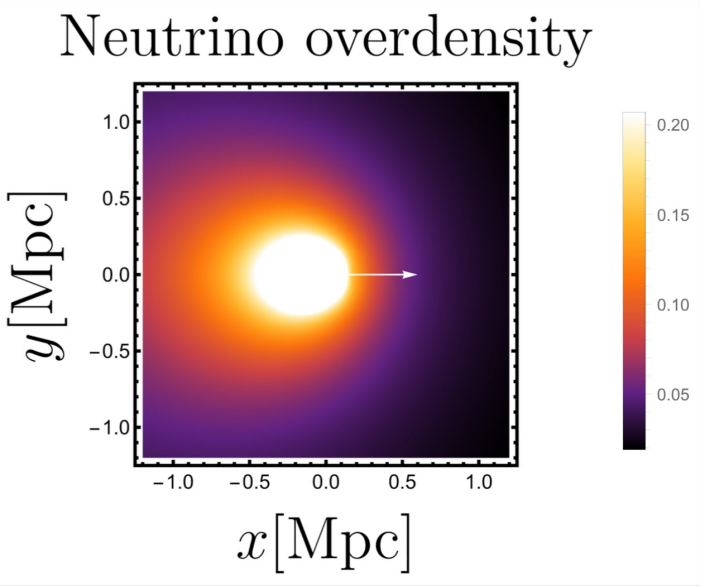
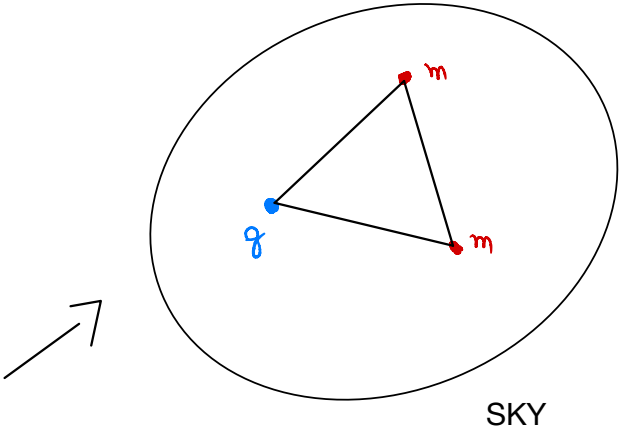
Caio Nascimento

Fundamental Physics from Future Spectroscopic Surveys

(LBNL May 2024)

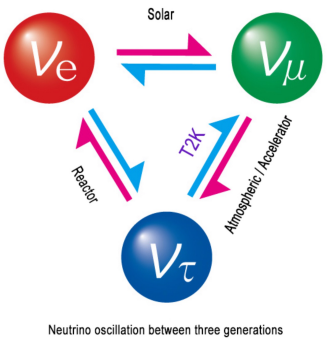
# Neutrino winds as a probe of neutrino masses



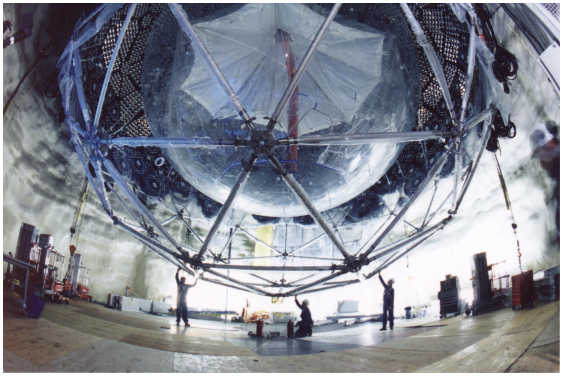




- Complementary to the traditional neutrino induced suppression of power
- Can potentially be detected with future spectroscopic surveys!

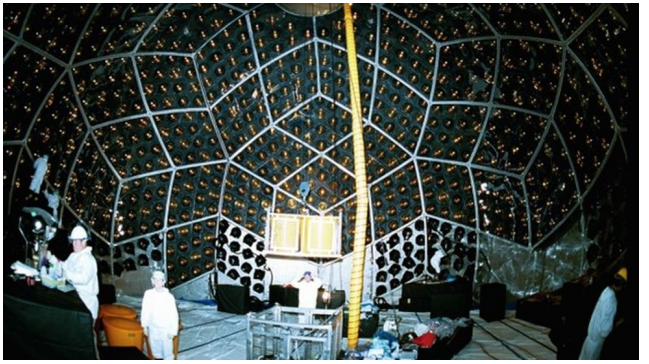
# Neutrinos are massive!



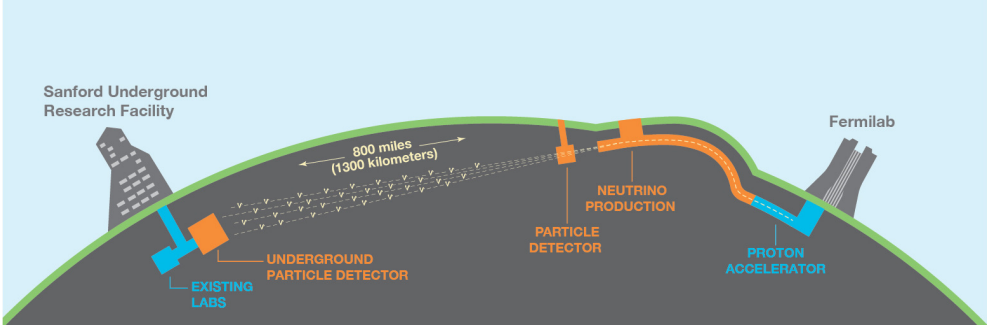

Credit: J-PART



Sudbury Neutrino Observatory



KamLAND detector




Deep Underground Neutrino Experiment (DUNE)

# On a hunt for the neutrino mass scale

- Current constraints

$$\sum m_\nu \geq 0.058\text{eV}$$

(Oscillation experiments)

$$m_\beta < 0.8\text{eV}$$

KATRIN

More stringent

$$\sum m_\nu < 0.12\text{eV}$$

Planck 2018

(or even $\sum m_\nu < 0.072\text{eV}$)

DESIY1

Not as robust

KATRIN Experiment

- Neutrino mass is BSM physics!

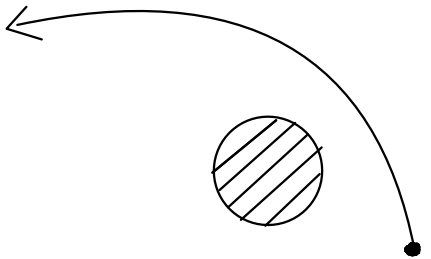
# Neutrinos free stream over cosmological distances

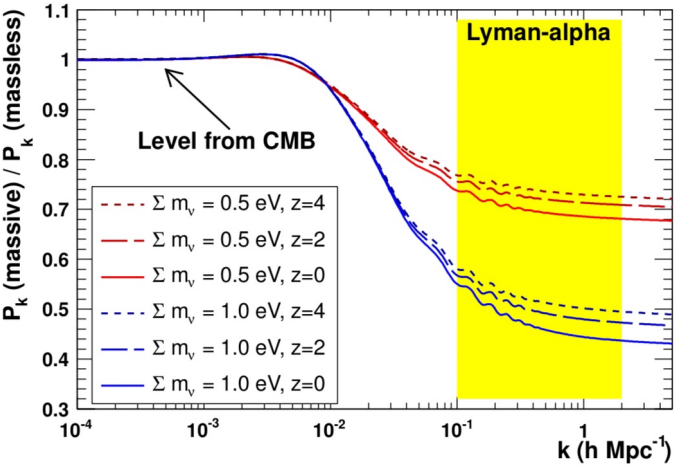
Nonrelativistic: $f_\nu \approx 0.5\%$

$$v_{\nu,0} \sim 3T_{\nu,0}/m_\nu \approx 1500\mathrm{km/s}$$

Prevents clustering os scales below:

$$\lambda_{\mathrm{fs}} \sim v_\nu/H_0 \approx 20\mathrm{Mpc}$$





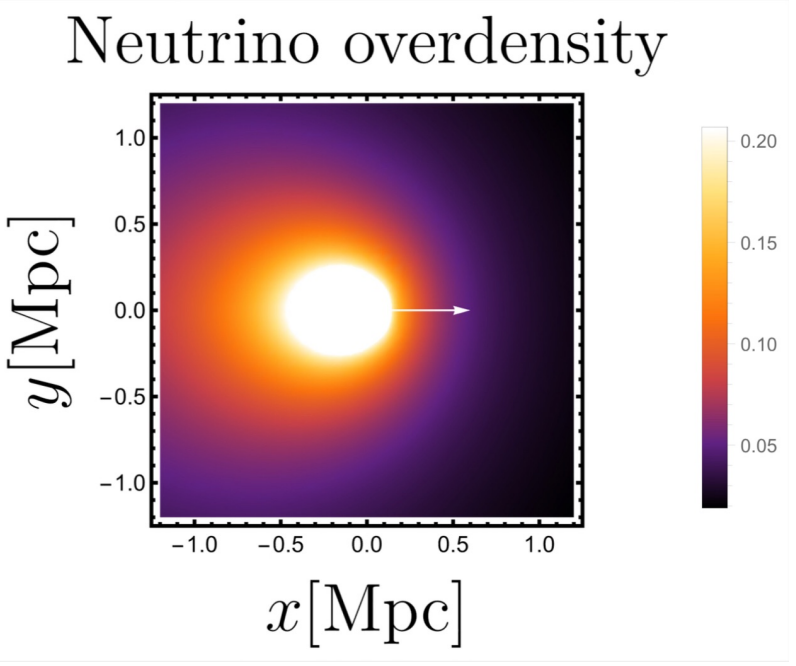

Credit: 1506.05976v3

# This is great…, but not perfect

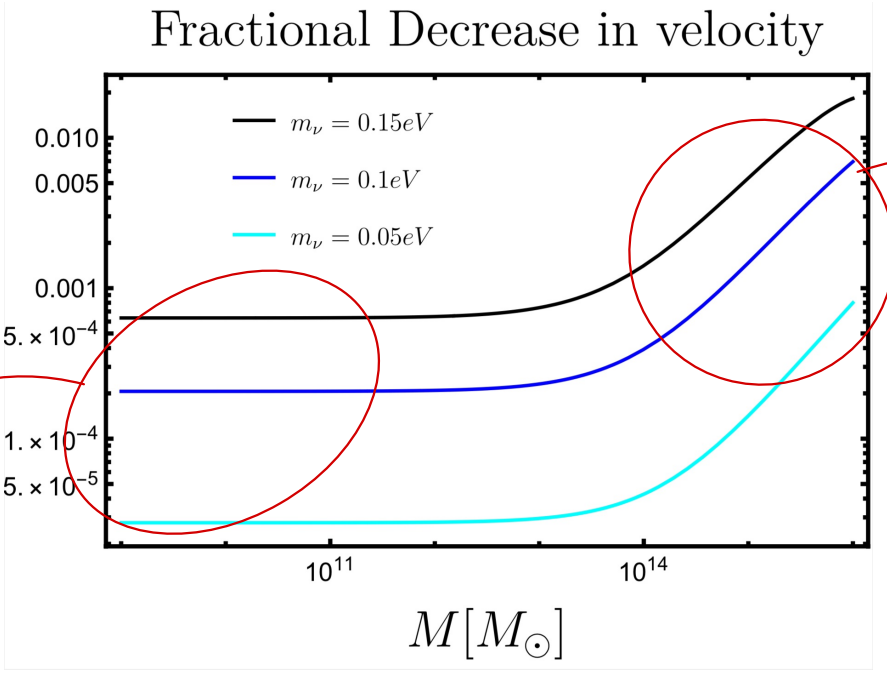
- Detection of the neutrino mass scale in the upcoming decade! → Accuracy and efficiency are key! (has kept me busy: 2107.05690, 2104.00703, 2303.09580)
- We should all care! → Set clear targets for laboratory searches
  Also see: Cosmological Implications of a Neutrino Mass Detection (2111.01096) Daniel Green, Joel Meyers
- BUT, there are degeneracies and sensitivity to modeling of small scales → New ideas!

# Neutrino winds: Basic idea

Peculiar motion of halos → Local dipole distortion to the neutrino density field



# Dynamical friction



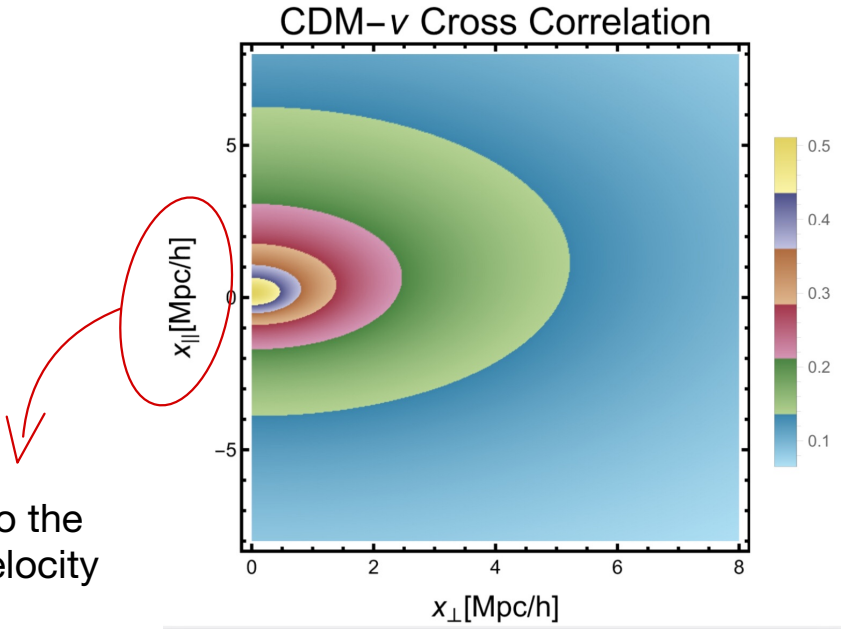

Halos are "surfing" on the wakes from larger halos (2 halo term)

Halos are "surfing" on their own wakes! (1 halo term)

# Dipole distortion

- Local cdm-nu cross correlation is modulated by the long-wavelength relative velocity

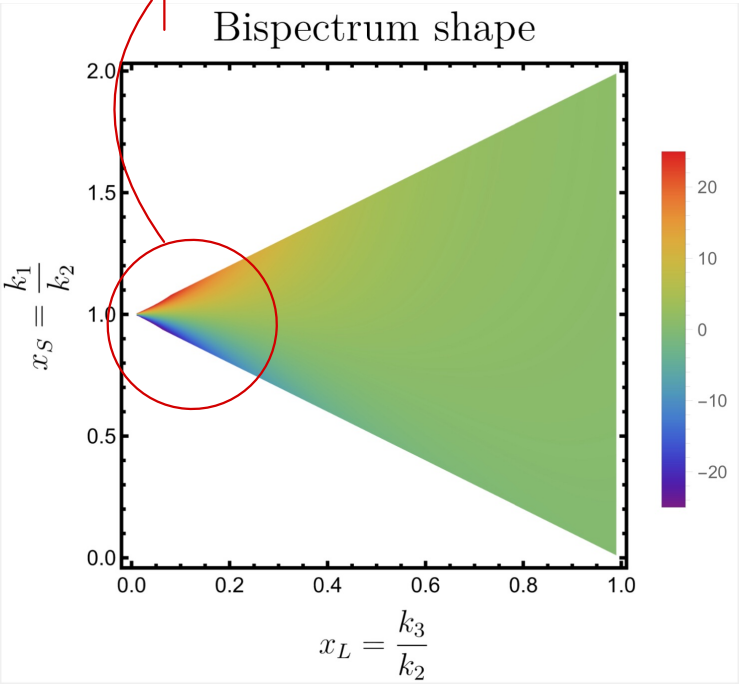
→ Really a three point function (stack against the relative velocity)




parallel to the relative velocity

# The bispectrum

Parity-odd under a cdm-nu flip



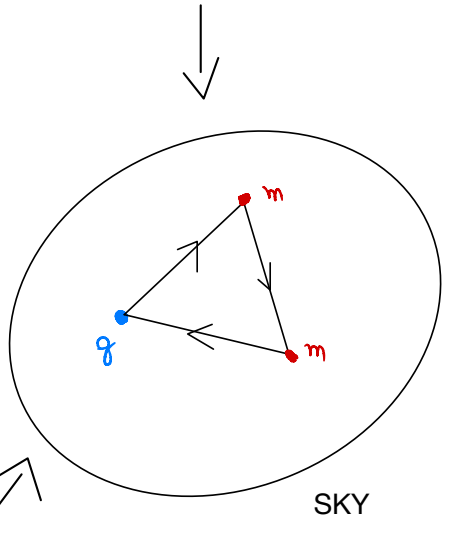

Amplitude:

$$f_{\rm NL}^{\rm eff} \approx 0.5 \ , m_\nu = 0.05{\rm eV}$$
$$f_{\rm NL}^{\rm eff} \approx 4 \ , m_\nu = 0.1{\rm eV}$$
$$f_{\rm NL}^{\rm eff} \approx 14 \ , m_\nu = 0.15{\rm eV}$$

- Different scaling $\sim \dfrac{x_S}{x_L}$
- NOT to be taken seriously!

# From real surveys…

Three point correlations to pick-up direction of relative velocity field




Cross-correlations to isolate nu-cdm dipole

Neutrino fraction

Linear bias

$$B_{\rm obs} = \frac{1}{2}\langle(\delta_{\rm m}\delta_{\rm g} - \delta_{\rm g}\delta_{\rm m})\delta_{\rm m}\rangle \approx \frac{1}{2} f_\nu b_{\rm g}\langle(\delta_\nu\delta_c - \delta_c\delta_\nu)\delta_c\rangle$$

Cleans out parity even contributions (exactly in the squeezed limit)

# Interesting features

- Window into mass splittings! $\text{signal} \sim m_\nu^3$

- It will take a billion galaxies to detect the neutrino winds assuming the minimal mass from oscillations!

- We want as many galaxies as possible in the local universe

# Conclusion

- Neutrinos are massive! Cosmological and laboratory experiments set complementary constrains on the neutrino sector.

- The matter power spectrum is suppressed due to neutrino free-streaming. We will measure the neutrino mass scale from this in the upcoming decade!

- Neutrinos accumulate downstream of moving halos, forming wakes. This is an independent probe of neutrino masses that may be detected by future (spectroscopic) surveys!