Neutrino cosmic viscosity and its effect on the CMB

- von Neumann equation

$$\imath(\partial_t - Hp\partial_p)\varrho_{\rm m} = [\mathcal{H}_{\rm m}, \varrho_{\rm m}]$$

- with the free neutrino Hamiltonian

$$\mathcal{H}_{\rm m} = \sqrt{M^2 + p^2\mathbb{I}}$$

- generating an increase in entropy

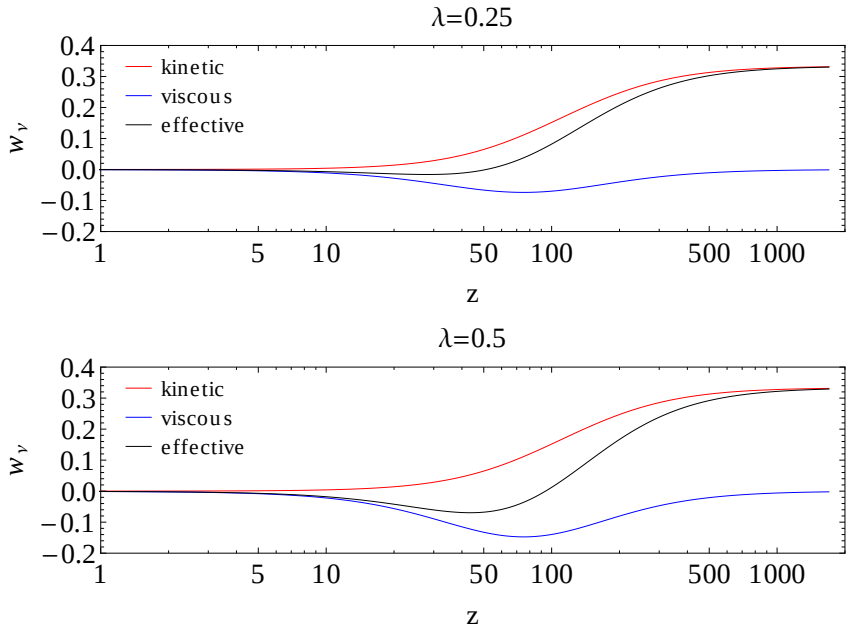
$$\dot{S}_\nu = -\int d\mathbf{q}\,\mathrm{Tr}\left[\dot{\overline{\varrho}}_{\rm m}\ln\left[\frac{\overline{\varrho}_{\rm m}}{\mathbf{I} - \overline{\varrho}_{\rm m}}\right]\right]$$

- and manifesting as a viscous pressure

$$P_\nu = P_k - \frac{\dot{S}_\nu n_a T_a}{9H^2}u^\lambda_{;\lambda}$$

- we assume an increase in entropy proportional to the change of the equation of state

$$\dot{S}_\nu = -\lambda\dot{w}_\nu \ln\left[w_\nu\right]$$



- which affects the CMB by the ISW effect