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### Neutrino radiation hydrodynamics in 3-dim'l Cartesian system

$$\begin{aligned} \frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) &= \frac{\partial \rho_\nu}{\partial t} \\ \frac{\partial(\rho \mathbf{v})}{\partial t} + \nabla \cdot (\mathbf{v} \rho \mathbf{v}) + \nabla P &= -\rho \nabla \phi \\ \frac{\partial E}{\partial t} + \nabla \cdot [(E + P) \mathbf{v}] &= -\rho \mathbf{v} \cdot \nabla \phi - \dot{Q}_\nu \end{aligned}$$

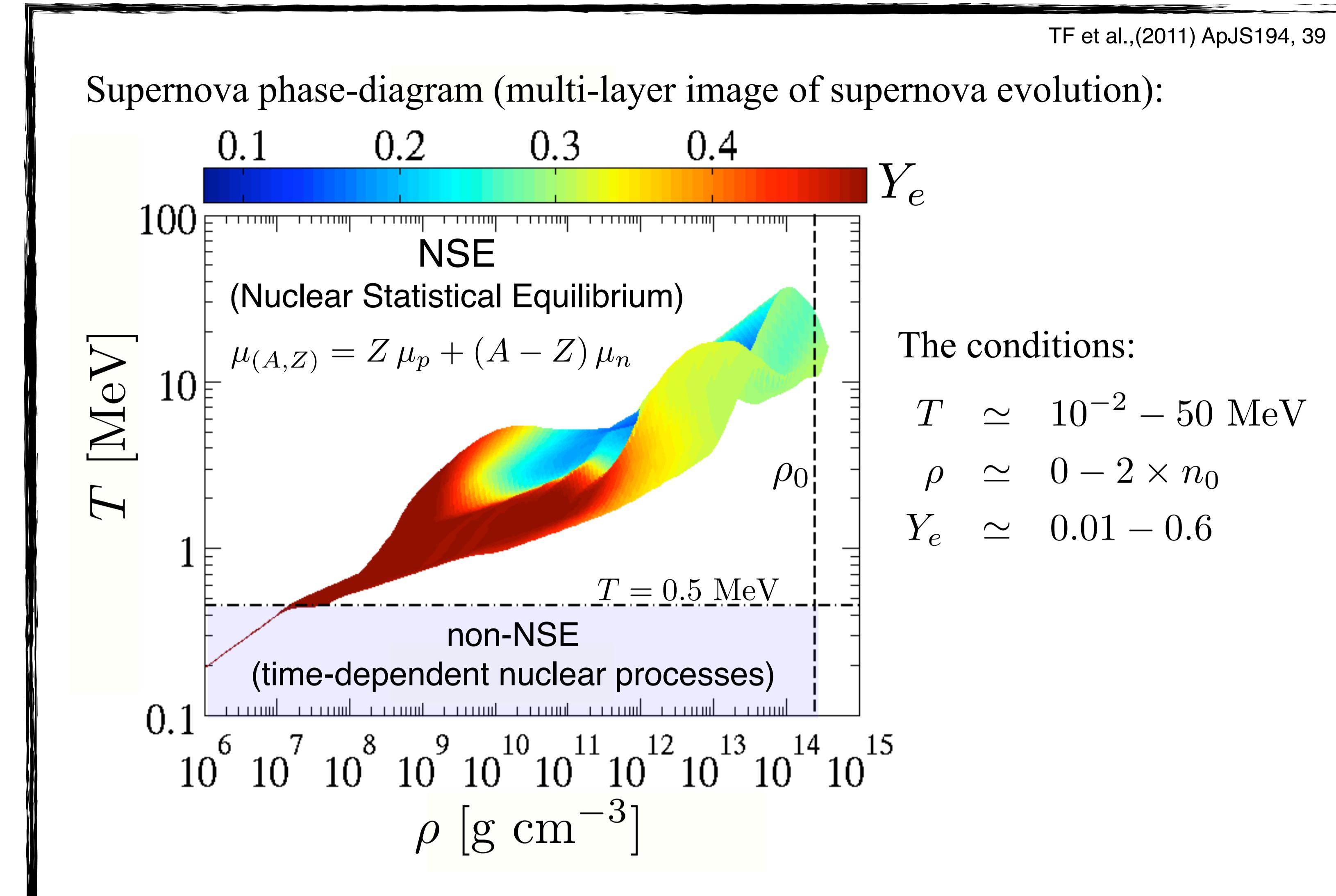
Käppeli et al., (2011) ApJS195, 16

$$\left\{ \begin{array}{l} E = \rho e + \frac{\rho}{2} \mathbf{v}^2 + \rho e_\nu \\ \phi \rightarrow \phi(r) = G \frac{m}{r} + \mathcal{O}(1/r^2) \end{array} \right.$$

TF et al., (work in progress)

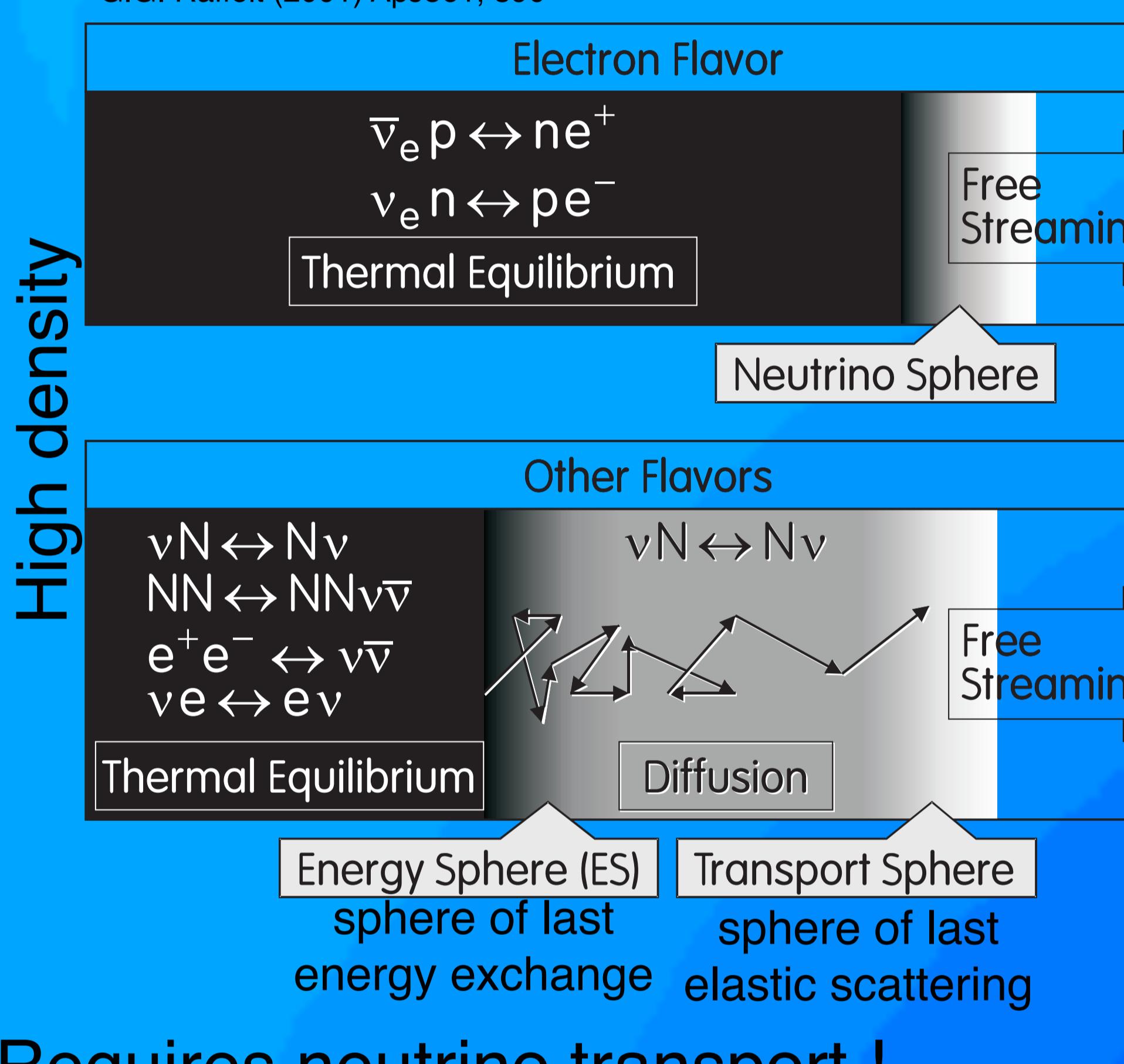
$$\begin{aligned} \frac{\partial f_\nu}{\partial t} (\mathbf{p}_\nu) &= -\frac{\mathbf{p}_\nu}{E_\nu} \cdot \frac{\partial f_\nu}{\partial \mathbf{x}} - \frac{d}{dt} \left( \frac{\mathbf{p}_\nu}{E_\nu} \right) \cdot \frac{\partial f_\nu}{\partial \mathbf{p}_\nu} \\ &+ j(E_\nu) (1 - f_\nu) - \frac{1}{\lambda(E_\nu)} f_\nu + E_\nu^2 \int d(\cos \vartheta') d\varphi R_{IS}(E_\nu, \cos \theta) (f'_\nu - f_\nu) \\ &+ (1 - f_\nu) \int E_\nu^2 dE_\nu d(\cos \vartheta') d\varphi R_{\nu\bar{\nu}}^p(E_\nu, E_\nu, \cos \theta) (1 - f_\nu) \\ &- f_\nu \int E_\nu^2 dE_\nu d(\cos \vartheta') d\varphi R_{\nu\bar{\nu}}^a(E_\nu, E_\nu, \cos \theta) f_\nu \end{aligned}$$

### EoS in supernova simulations

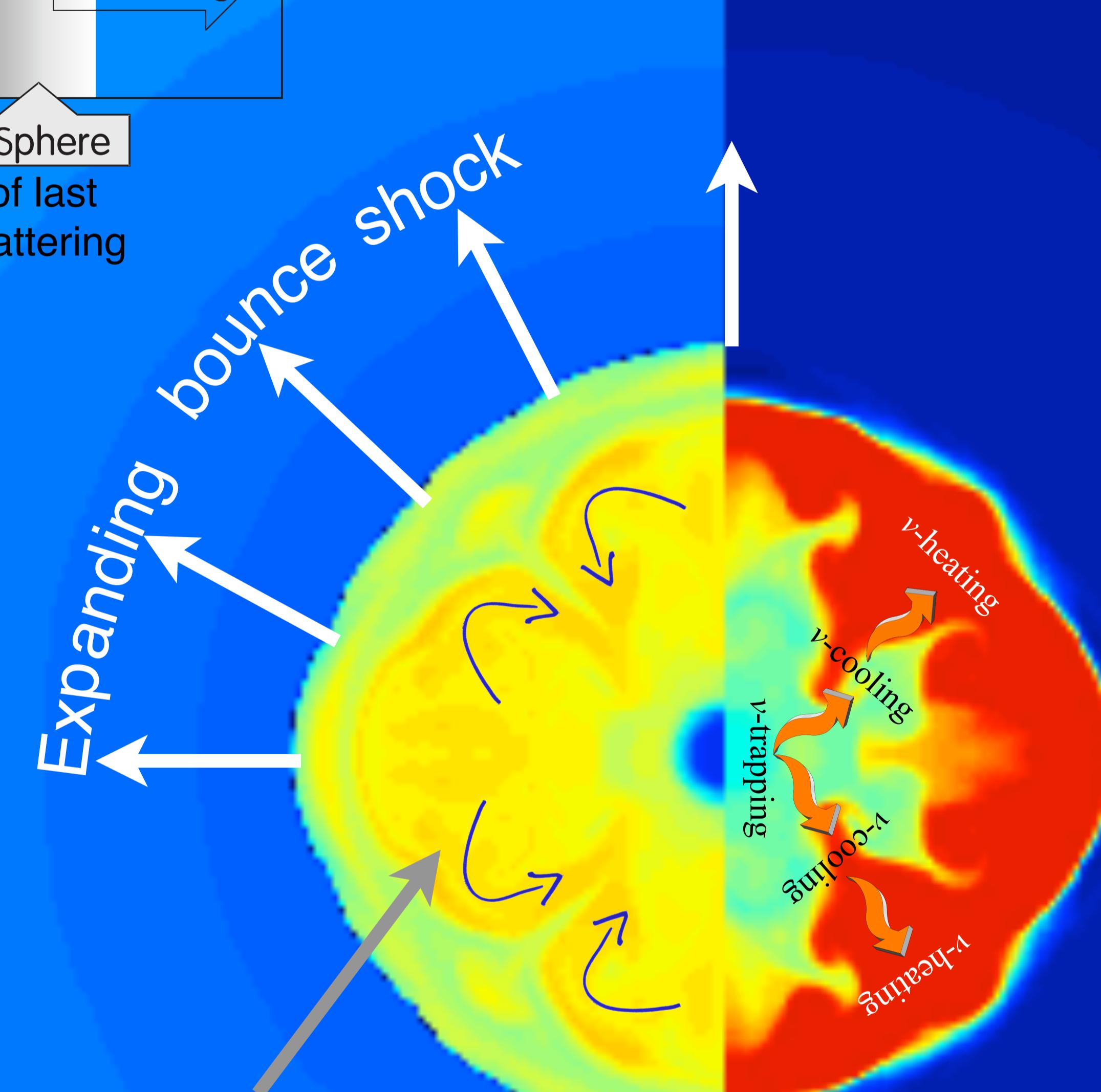


### Neutrino decoupling from matter

G.G. Raffelt (2001) ApJ561, 890

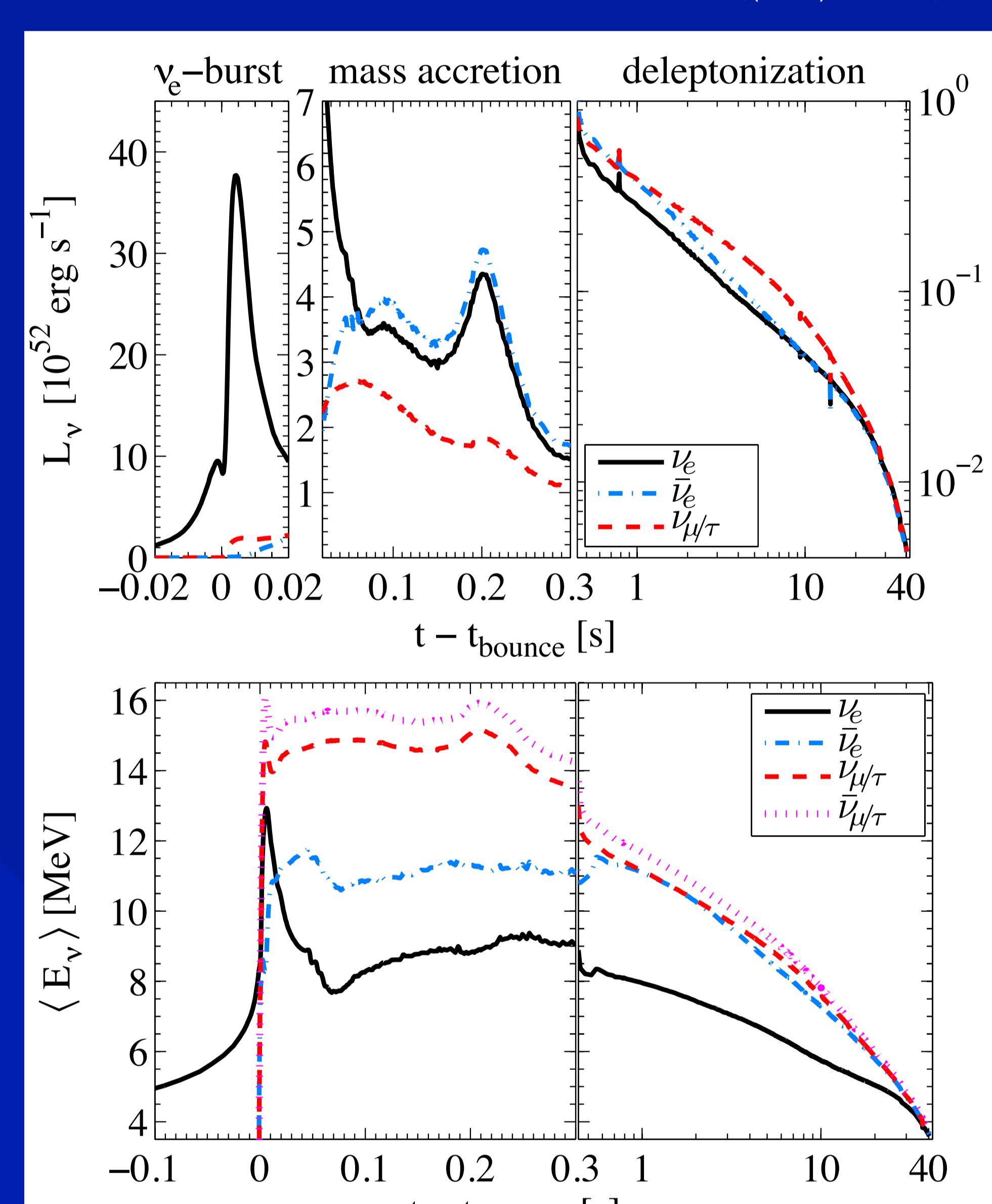


Requires neutrino transport !



### Neutrino signal from 1-dim'l simulations

TF et al., (2010) A&A517, A80



### Role of light nuclear clusters

TF et al., (2014) EPJA50, 46

