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Neutrino Distributions for a Rotating Core-Collapse Supernova with a Boltzmann-Neutrino-Transport

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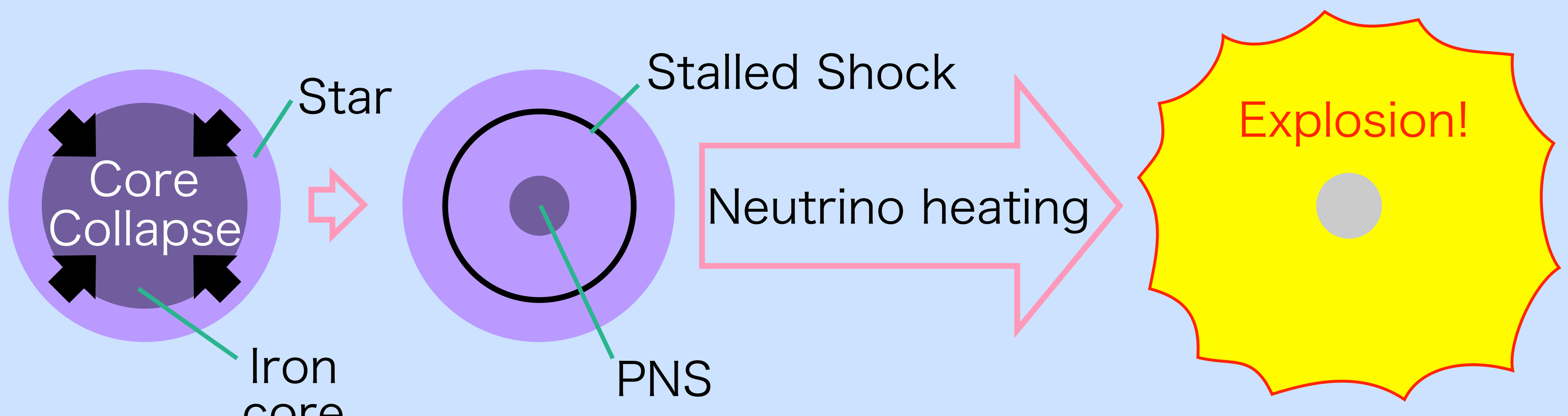
Abstract

By a Boltzmann-radiation-hydro simulation, we examined the effects of rotation on the neutrino distributions.

1. Introduction

The Core-Collapse Supernovae (CCSNe) are supposed to explode by the neutrino-heating mechanism. The 1D-Boltzmann-radiation-hydro code revealed that CCSNe do not occur under the spherical symmetry. Recently multi-D CCSNe simulations show successful shock revival, but they all use approximate neutrino solver. Therefore, we developed the multi-D-Boltzmann-radiation-hydro code and performed several simulations. However, these models are non-rotating and the neutrino distributions are symmetric w. r. t. the r-θ plain. In order to break such symmetry, we imposed the rotation on the progenitor, and investigated the effects on the neutrino distributions.



Neutrino-heating mechanism

2. Method

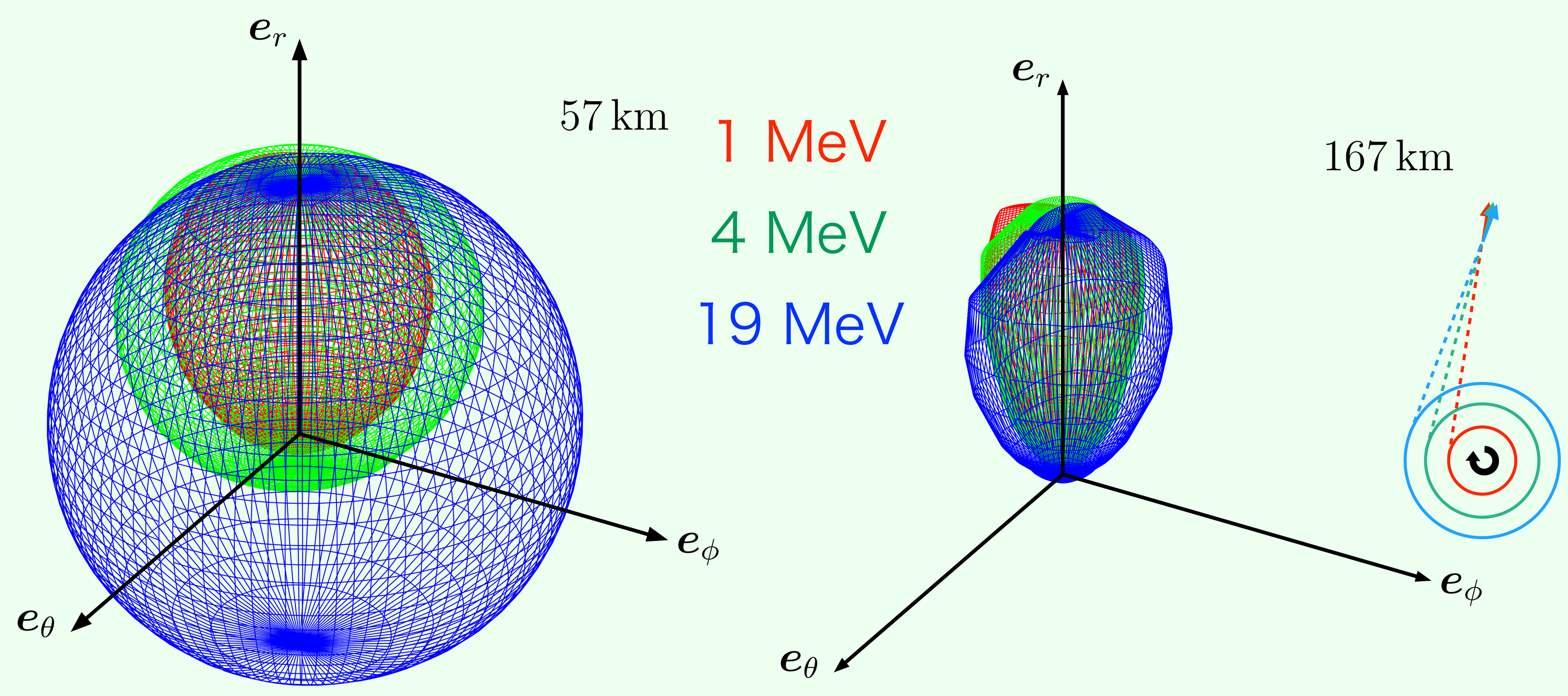
Code: Boltzmann-radiation-hydro code (see Kosuke's talk)
Progenitor: 11.2 M⊙ in Woosley et al. (2002)
Rotation profile: sheller $\Omega(r) = \dfrac{1\,\mathrm{rad/s}}{1 + (r/10^8\,\mathrm{cm})^2}$

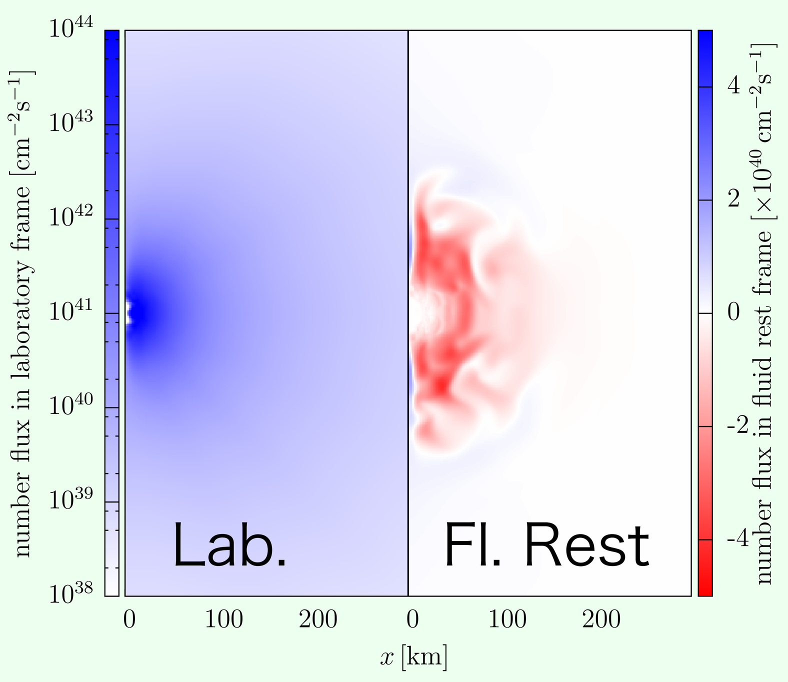
Neutrino reactions: Bruenn's standard set
+ GSI electron capture rate, Nucleon bremsstrahlung
Equation of State: Furusawa's multispecies EOS
Grid number: $(N_r, N_\theta, N_\nu, N_{\bar{\theta}}, N_{\bar{\phi}}) = (384, 128, 20, 10, 6)$

3. Results

・In the semitransparent regions, low energy neutrinos are more loosely trapped by the matter and show forward peaked distributions than high energy neutrinos.
・In the optically thin regions, all neutrinos are forward peaked, but high energy neutrinos are tilted in the ϕ-direction. Because of the matter rotation, emitted neutrinos have rotational velocities. The angle from the r-direction decreases according to the distance from the neutrinosphere. Since the neutrino sphere for higher energy neutrinos are larger, the angle increases according to the neutrino energies.

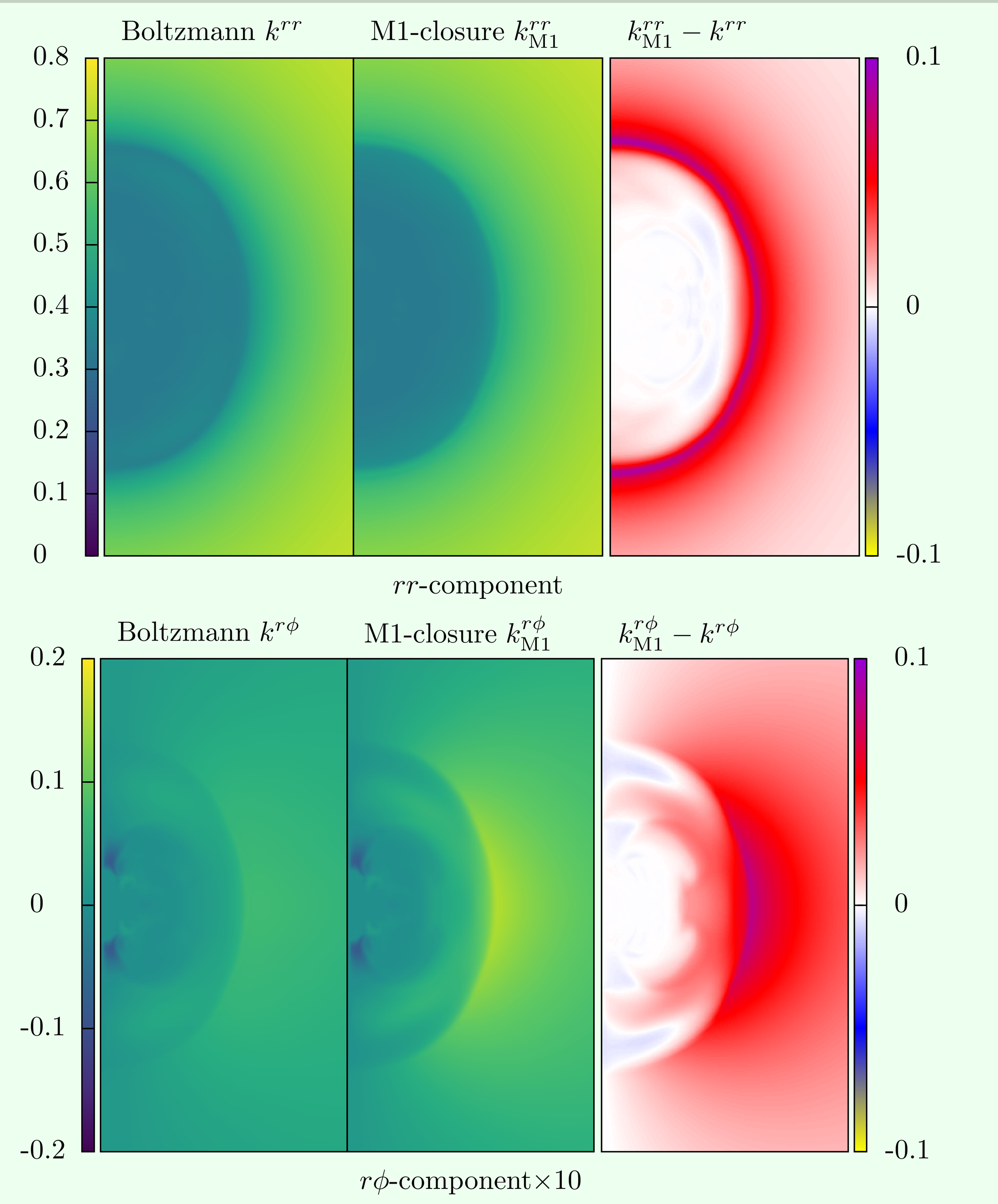
Angular distributions of neutrinos





ϕ-component of the neutrino number flux in the lab. (left) and fluid rest (right) frame. (cannot be captured in the Ray-by-ray approx.)
・Due to tilted distributions, the neutrino flux has positive rotational components in the laboratory frame.
・In the fluid rest frame, neutrinos are overtaken by the fluid and has the negative flux.

The Eddington tensor is compared with the M1-closure method.
・The rr-component shows faster transition from the optically thick limit to the thin limit for the M1-method. This is because M1 determines the Eddington factor only by the flux factor.
・The rϕ-component in M1 is ~2 times as large as the Boltzmann calculation. This has non-negligible effects on F^ϕ compared with $\phi\phi$-component.



4. Summary

Because of the rotation, the neutrino distributions are tilted in the ϕ-direction, and the rotational component of the flux emerges. An approximate method of neutrino transfer, M1-closure scheme, is tested and the limitation is presented.