Neutrino-Nucleus Interactions in Central Engine of Core-Collapse Supernovae ID 324

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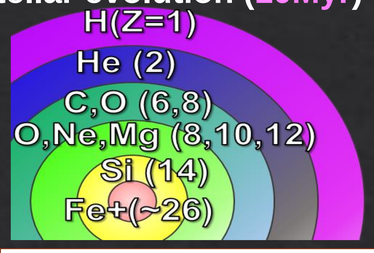
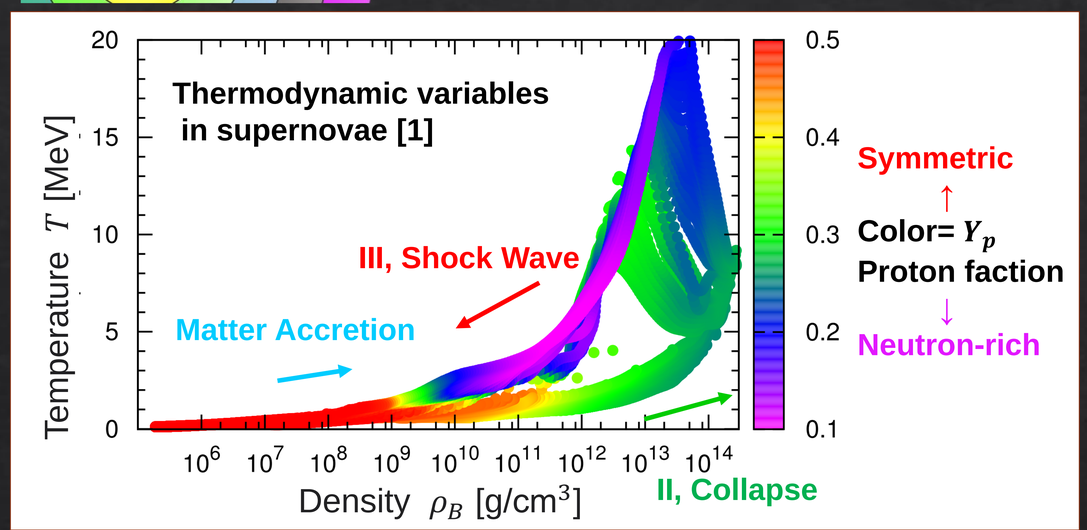
I. Core-Collapse supernovae

Stellar evolution (10Myr)

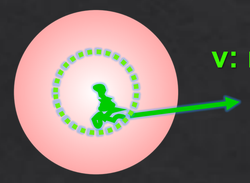


- Death of Massive stars ($\geq$ ~10 solar mass)
- Energetic: 10^{51}erg (ejecta) 10^{53}erg (neutrino)
- Emissions of neutrinos and gravitational waves
- Formation of a neutron star or a black hole
- Nucleosynthesis site of heavy elements
- Extreme test for neutrino-nuclear physics



II, Neutrino-Nucleus Interactions during core collapse

Core-collapse of Fe core (0.1sec)



Dominant neutrino reactions

Nuclear Electron Capture

$(N,Z)+e^- \rightarrow (N+1,Z-1)+\nu_e$

Neutrino coherent scattering

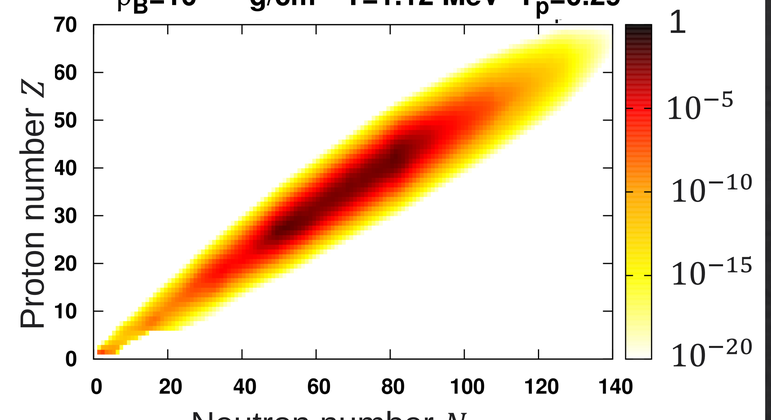
$(N,Z)+\nu \rightarrow (N,Z)+\nu$

- Nuclei with (N,Z)≈(40-80,25-40) are abundant [2].
- There is still uncertainty about nuclear excitation model [2] and electron capture rates [3]
- Supernova Neutrino Observations may be greatly changed [3]

Nuclei at the center of collapsing core when neutrinos start to be trapped[1].

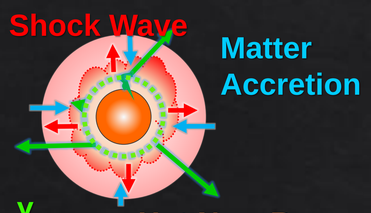
Mass Fraction $X(N,Z)=\frac{(N+Z)n_{AZ}}{\sum(N+Z)n_{AZ}}$

$\rho_B=10^{12.0}$ g/cm^3 T=1.12 MeV Y_p=0.29



III, Neutrino-Nucleus during shock propagation

Shock wave propagation in Fe core (1sec)



Dominant neutrino reactions

$p+e^- \leftrightarrow n+\nu_e$

$n+e^+ \leftrightarrow p+\overline{\nu_e}$

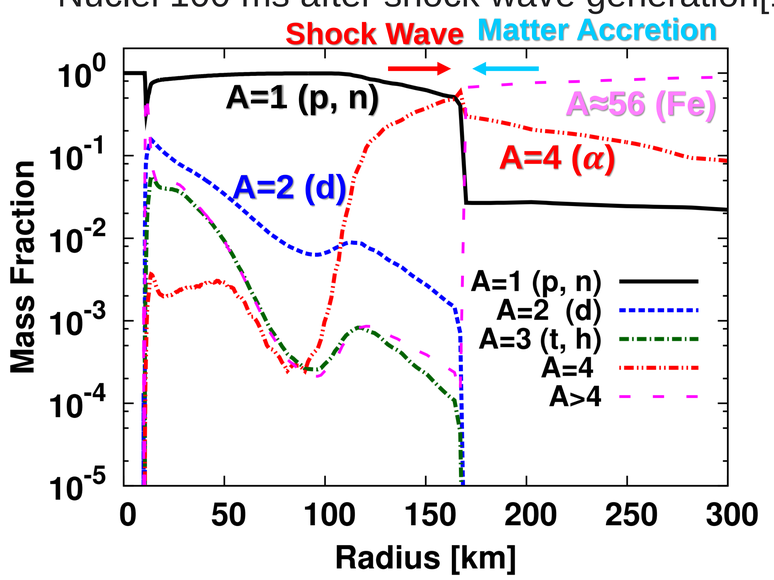
$d+e^- \rightarrow n+n+\nu_e$

$d+\nu_e \rightarrow p+p+e^-$

$d+\overline{\nu_e} \rightarrow n+n+e^+$

- Clustering (appearance of deuteron (A=2) reduces protons and neutrons that are dominant sources of neutrino emission and absorption. [4]
- Neutrino emission and absorption of deuteron are also non-negligible (~ 10%) [4,5].
- α-particle (A=4) contribution is negligible [5].

Nuclei 100 ms after shock wave generation[1]



IV. Summary

- Nuclei with (N,Z)≈(40-80,25-40) during the collapse affect core deleptonization and ν emissions
- Deuteron formation and weak interactions affect shock dynamics and ν emissions
- Sophistications of neutrino reaction calculations and supernova simulations are required.

[1] S. Furusawa, Physica Scripta, 95, 7, 074002 (2020)
[2] S. Furusawa, Phys. Rev. C 98, 065802 (2018)
[3] S. Furusawa, H. Nagakura, K. Sumiyoshi, C. Kato & S. Yamada, Phys. Rev. C 95, 025809 (2017)
[4] H. Nagakura, S. Furusawa, H. Togashi, S. Richers, K. Sumiyoshi, S. Yamada Astrophysical J. Suppl. 240, 38 (2019)
[5] S. Furusawa, H. Nagakura, K. Sumiyoshi & S. Yamada, Astrophys. J., 774. 78. (2013)