Lifting the core collapse supernova bounds on keV mass sterile neutrinos

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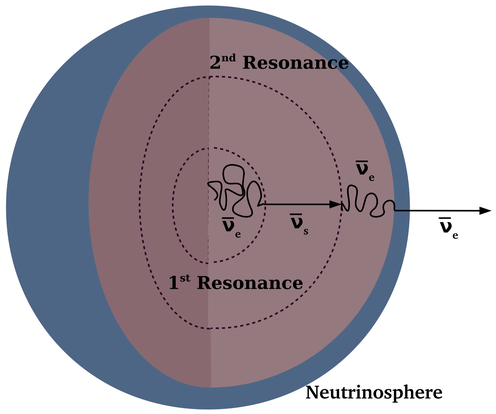
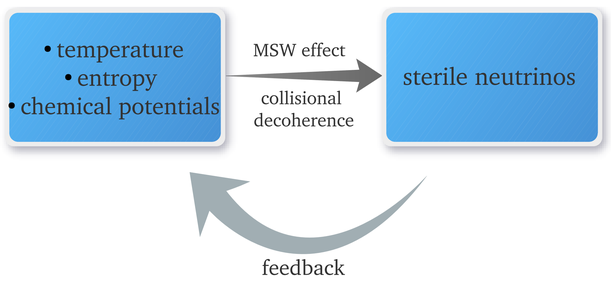
A glimpse: sterile neutrinos inside supernovae

- **Sterile neutrinos:**
  - **Can carry away the energy from the proto-neutron star, possibly weaken the supernova shock energy**
  - **Change the electron fraction affecting the supernova dynamics**
  - **Change the reaction equilibrium in the core**
- **Highly energetic sterile neutrinos produced at the 1st (inner) MSW resonance, can reconvert to active ones at the 2nd (outer) resonance, and indirectly enhance the neutrino heating**



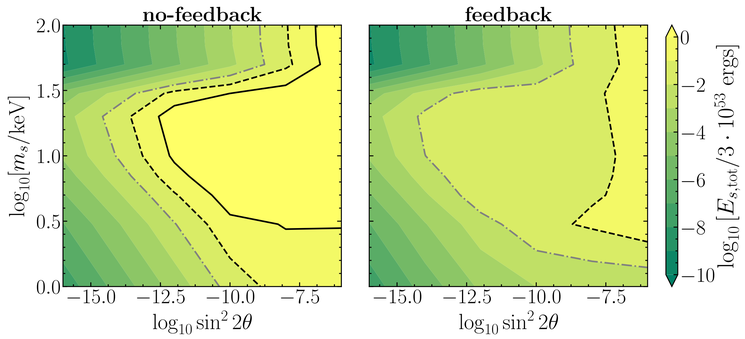
[1]

What is the feedback and why it is important?



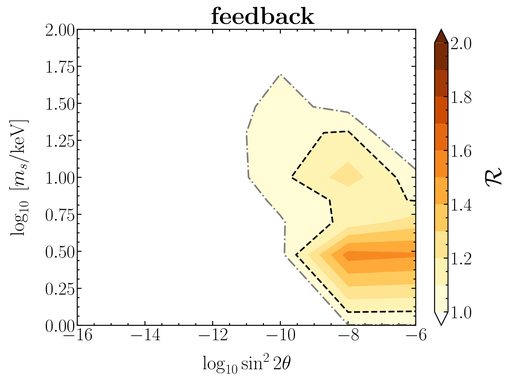
The hydro and particle background, together with the mixing parameters, determine the number of sterile neutrinos produced by the MSW mechanism and collisional decoherence. The active neutrinos after being converted to sterile ones effectively disappear, and since they were strongly coupled to the rest of the particles in the medium, a new equilibrium state forms. The change imposed on the chemical potentials, temperature, and entropy is referred to as a feedback. In our work, we included the dynamical feedback on the supernova background by imposing the conservation laws.

New treatment of active-sterile neutrino mixing in supernovae challenges sterile neutrino bounds



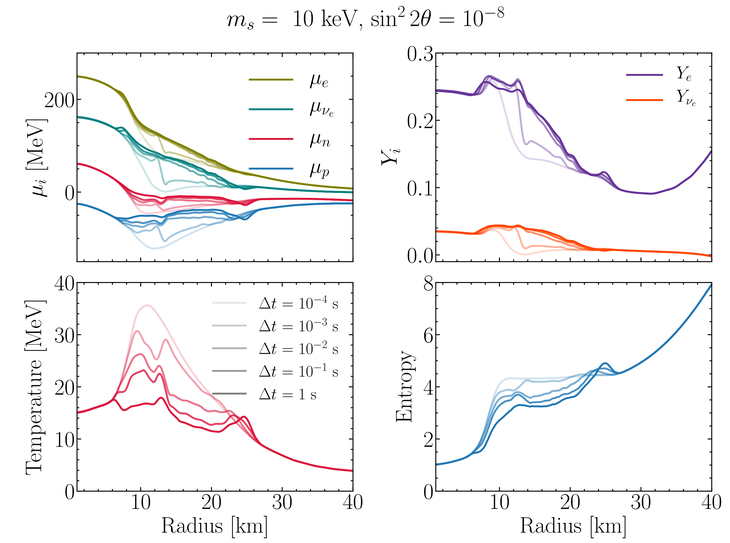
The active neutrinos carry most of the stellar binding energy during the core-collapse. If sterile neutrinos exist, they mix with the active ones and escape the star removing a fraction of the energy. This could lead to a much faster proto-neutron star cooling than the one explaining the observed duration of the neutrino signal from SN1987A. This logic lets us constrain the mass and mixing angle of the sterile neutrino. The excluded parameters allow sterile neutrinos to carry away energy larger than $3\cdot10^{53}$ ergs. The plot above shows the comparison of results for calculations with and without the dynamical feedback. *It suggests that self-consistent calculations no longer exclude the sterile neutrino with mixing parameters in the phase space allowed by dark matter searches.*

Can sterile neutrinos aid the supernova explosion?



The energy deposited by sterile neutrino reconversion in the outer layer of the core outgrows the gravitational binding energy of that layer in a small region of the parameter space $\mathcal{R} > 1$. This may cause the outer layer of the stellar core to expand and intensify the emission of active neutrinos. As an indirect consequence, neutrino heating may increase [2,3].

Sterile-active neutrino conversions modify the hydro and particle background in supernovae



The production of sterile neutrinos changes the particle chemical potentials through the dynamical feedback. Moreover, the sterile neutrino cooling (conversions) and heating (reconversions) modify the entropy and the temperature of the medium. The temperature decreases in regions with the most prominent neutrino conversions and increases where the reconversions are effective. We presume that the variation of the electron fraction may modify the proto-neutron star evolution, and as a consequence, affect the supernova explosion.

Conclusions

- **Sterile neutrinos with keV mass:**
  - **have a major impact on the supernova physics**
  - **lead to the growth of the lepton asymmetries**
  - **might possibly aid the explosion mechanism**
- **Inclusion of the dynamical feedback significantly weakens supernova bounds on keV sterile neutrinos**

Selected references

Based on: A. M. Suliga, I. Tamborra, M-R. Wu, arXiv:2004.11389 [astro-ph.HE] and arXiv:1908.11382 [astro-ph.HE]

1. Figure based on: L. Walk, *Neutrino Gyroscopes!*
2. J. Hidaka, G. M. Fuller, arXiv:0706.3886 [astro-ph.HE]
3. M. L. Warren et al., arXiv:1405.6101 [astro-ph.HE]