Long-term supernova simulation with axion-like particles

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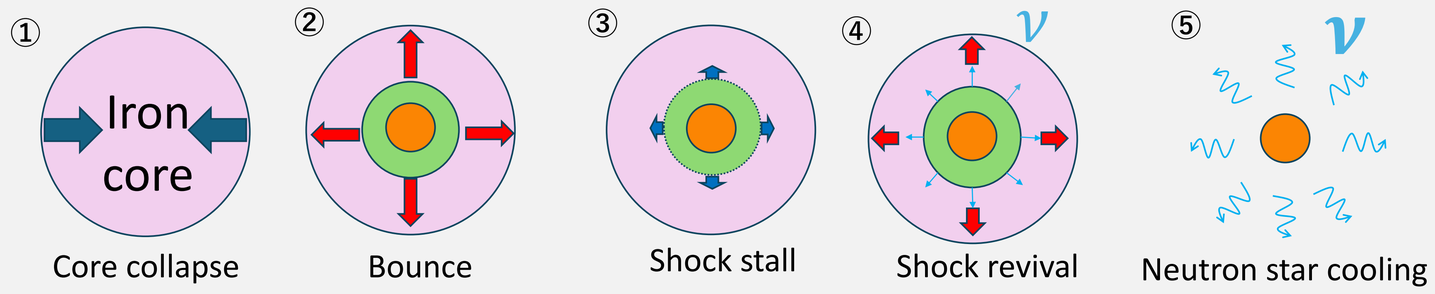
Supernova

- The most energetic explosion in the universe
- Neutrinos play a key role and 99% of the energy emitted as neutrinos
  - ◆ Important to observe supernova neutrinos
- Neutrino emission lasts over 1min.
  - ◆ Important to calculate for a long term

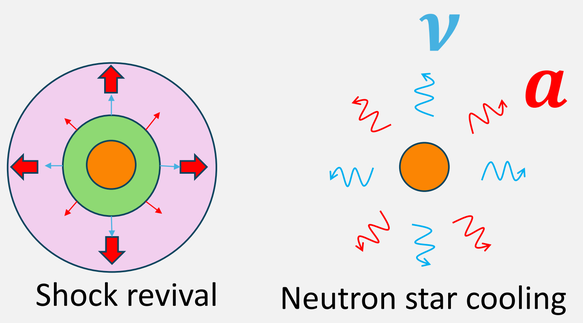


Axion-like particles

- Beyond standard model particle introduced to solve the strong CP problem (**Axion**)
- Pseudo-scalar particles like an axion
  - ◆ **Axion-like particles (ALPs)**
- Effects of ALPs on supernovae
  - □ Enhance heating (Early phase)
  - □ Accelerate neutrino cooling (Late phase)

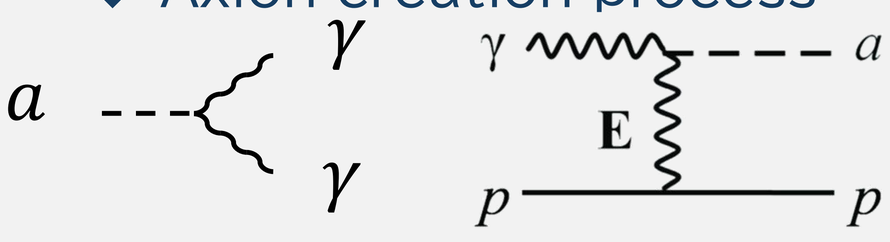
In this study

- To calculate supernovae with ALPs for a long term
- To predict neutrino events in the case that ALPs exist



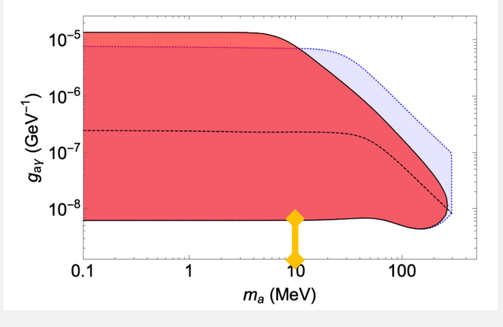
Simulation

- Simulator: GR1D
  - ◆ 1D
  - ◆ General relativity
  - ◆ Neutrino radiation hydro
- Implemented with ALP cooling
  - ◆ Axion creation process



Photon coalescence Primakov effect

  - ◆ Axion mass: 10 MeV
  - ◆ Coupling Constants
    - □ $6.0 \times 10^{-9}\mathrm{GeV} \sim 1.0 \times 10^{-9}\mathrm{GeV}$

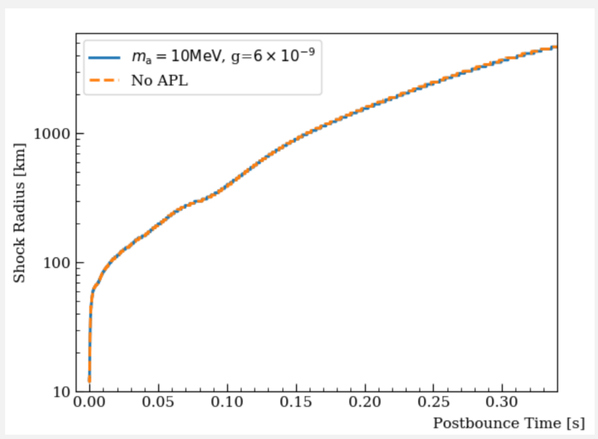


- EOS: DD2
  - ◆ Relativistic mean field theory
- Progenitor: 9.6 $M_\odot$

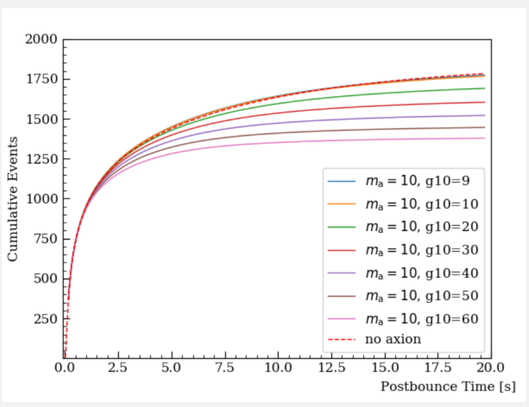
Results

10kpc with Super-Kamiokande

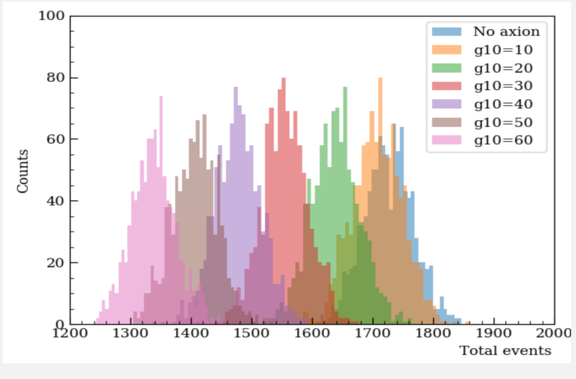
Shockwave



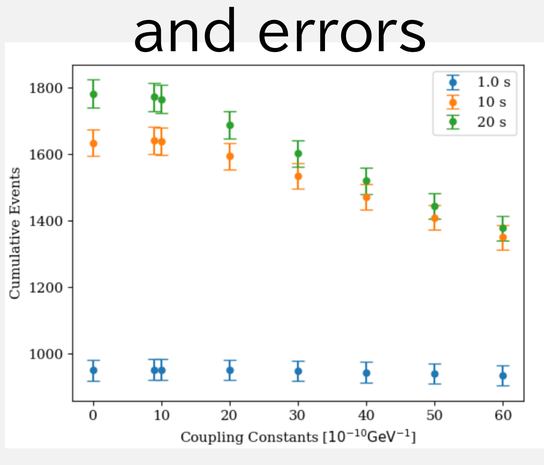
Cumulative events



Event number histogram



Cumulative events and errors



Conclusion

- **We can detect ALPs from long-term supernova neutrinos**