

Supernovas and Nuclear Neutrinos

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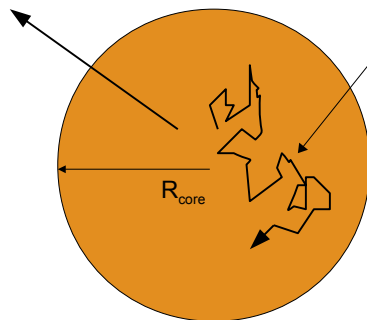
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Neutrinos Cool Core and Produce Signal

Low energy neutrino



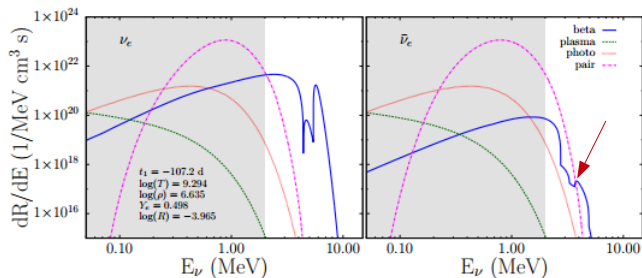
Photon or energetic neutrino

- No trapping during silicon burning and at onset of collapse
- Before trapping, core produces neutrino signal
- Promise of powerful neutrino detectors gives hope of detecting supernova even before collapse!

Neutrino Production Mechanisms

- Beta processes (electron/positron capture and emission)
- Neutral current de-excitation
- Bremsstrahlung
- Photo process
- Pair annihilation
- Plasmon decay

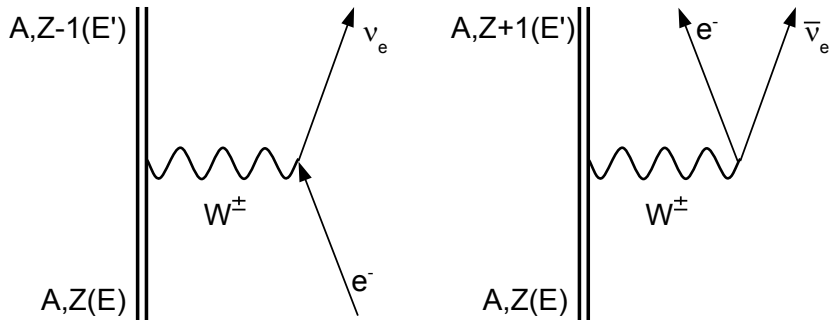
Pre-collapse Neutrino Spectra



Patton & Lunardini (2015)

- Nuclear neutrinos dominate in some energy regions
- Certain spectral features due to specific nuclei
- Beta process neutrino spectra produced using single effective Q-value and transition strength

Beta Processes

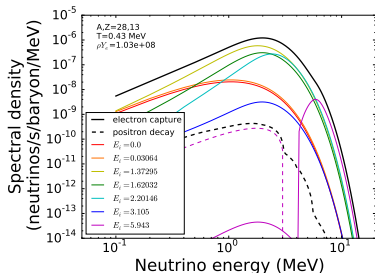
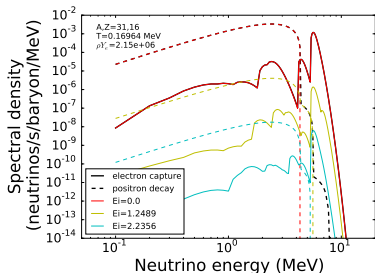
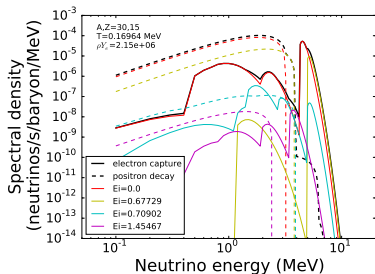
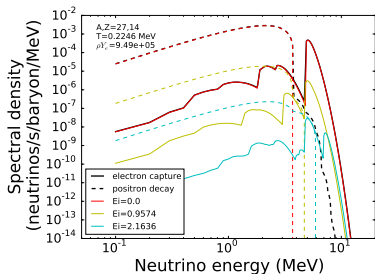


- Charged lepton can be electron or positron
- Produces electron flavored (anti-)neutrino
- Initial and final states can be excited states

We need energy levels and transition strengths

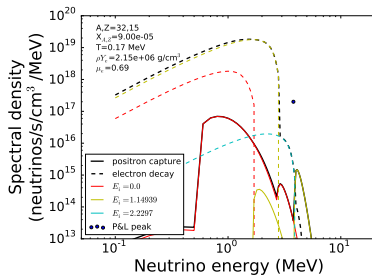
- Use OXBASH shell model code
- sd model space with USDB Hamiltonian
- Compute energy levels and transition strengths
- Thermally populate excited states and compute thermal average neutrino spectrum

Beta Neutrino Spectra

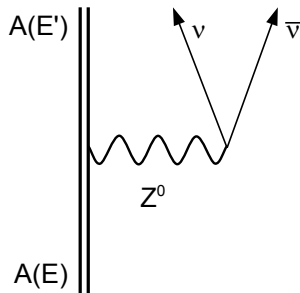


^{32}P Beta Anti-Neutrino Spectrum

- P&L peak high by 2 orders of magnitude
- Correct accounting of nuclear structure has profound effect



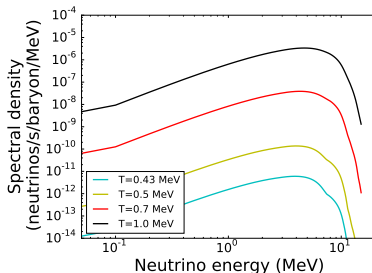
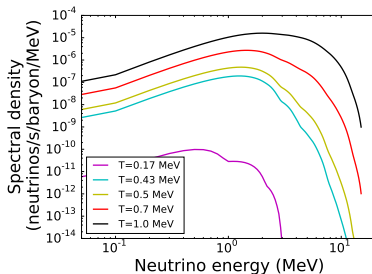
Neutral Current Neutrino Pairs



- Nucleus relaxes from excited state. Final state may be excited.
- Can produce any flavor (anti)neutrinos
- Nuclear structure, strength, and thermal averages computed similarly to the beta processes

Neutral Current Neutrino Spectrum

- ^{27}Al (top) and ^{28}Si (bottom)
- Spectra similar above 10 MeV neutrino energy
- Little contribution at low temperature
- Rises *very rapidly* with increasing temperature
- Could be dominant source of high energy neutrinos at late times



Summary and Future Work

- Stars with mass greater than 8-10 solar masses die catastrophically
- Nuclei and neutrinos play critical roles
- We may eventually be able to detect pre-supernova neutrinos
- Need to consider nuclear structure to get correct neutrino spectra
- Neutral current de-excitation is likely very important at late times
- We have initiated project to compute nuclear neutrino spectra over wide range of nuclear masses, temperatures, and densities