Estimating the Neutrino Flux from X-ray Bursts

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Type I X-ray bursts are thermonuclear explosions on the surface of accreting neutron stars in low-mass X-ray binaries. They are highly energetic ($\sim 10^{38}$ erg) events and so can release energy in the form of neutrinos. The neutrino flux released during an X-ray burst comes primarily from β-decays [3, 4]. Using KEPLER [5], a 1D implicit hydrodynamics code that calculates the full nuclear reaction network, we have measured the neutrino fluxes of type I bursts for a range of initial conditions. We find that neutrino losses are between 6×10^{-5} (low hydrogen fraction) and 0.185 (high hydrogen fraction), of the total energy per nucleon, $Q_{\rm nuc}$. We also find a dependence on the neutrino flux with metallicity of the accreted fuel. Recent literature often uses the approximation formula $Q_{\rm nuc} = 1.6 + 4\ \bar{X}\,{\rm MeV/nucleon}$ where $\bar{X}$ is the average hydrogen mass fraction of the ignition column to estimate $Q_{\rm nuc}$ and hence fuel composition. We find this expression is a very poor fit (rms = 0.4..) to the KEPLER predictions. We attribute the discrepancy to the assumption of $35\,\%$ energy loss due to neutrinos during the rp and αp processes [1] in this expression, however, it is only at β-decays that $\sim 35\,\%$ of energy is lost due to neutrino emission [3, 4], and β-decays do not contribute much to the total energy. Using total measured burst energies from KEPLER for a range of initial conditions, we have determined a new approximation formula, $Q_{\rm nuc} = 0.93 + 7.41\bar{X} - 1.88\bar{X}^2$ ${\rm MeV/nucleon}$, with a root mean square error (RMS) value of 0.07 MeV/nucleon, compared to the old relation that has an RMS value of 0.47 MeV/nucleon.

References

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