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sntools: An event generator for supernova burst neutrinos

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Software

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Summary

Supernovae are stellar explosions that produce many of the chemical elements necessary for life to exist and form neutron stars and black holes. However, despite millennia of observations and almost a century of in-depth study, the explosion mechanism of supernovae is not yet well understood.

Observing the neutrino signal from the next galactic supernova can help solve this puzzle. To prepare for this once-in-a-lifetime event, it is essential to study how various detectors respond to the neutrino fluxes from different supernovae. sntools helps with this by providing a link between computer simulations of supernovae and those of neutrino detectors: From the neutrino fluxes predicted by a given supernova model, it generates data sets of neutrino interactions, taking into account detailed, energy-dependent cross-sections for all relevant interaction channels. These data sets can then be used as input for a full detector simulation and event reconstruction toolchain.

Statement of Need

sntools is an event generator for supernova burst neutrinos which is written in Python and makes extensive use of numpy (Walt et al., 2011) and scipy (Virtanen et al., 2020). It currently supports multiple detector configurations using either water, liquid scintillator or water-based liquid scintillator as a detection material. It also supports several different input formats for neutrino fluxes from various computer simulations. New detector configurations, materials or input formats can be added easily.

sntools was initially developed to study supernova model discrimination with Hyper-Kamiokande (Migenda, 2019) and is also used to develop a supernova DAQ system for the same experiment. More recently, sntools was adapted by the WATCHMAN (Askins et al., 2015) experiment and for early studies for the THEIA detector concept (Askins et al., 2020).

A few other software packages related to supernova neutrinos already exist. SNOwGLoBES (SNOwGLoBES contributors, 2020) is widely used to compute event rates and energy distributions for supernova burst neutrinos in various different detectors. While it is an excellent tool for preliminary studies or quick comparisons of different detector configurations, it uses simplified approximations for detector effects like energy resolution or threshold. It is an event rate calculator—not an event generator—and states in its own documentation that it is "not intended to replace full detector simulations." In contrast, sntools is intended for use in conjunction with a full detector simulation to perform more advanced, in-depth studies.

Software that performs a similar role to sntools was likely also created by several different neutrino experiments. However, it often is not publicly available or in use beyond the experiment it was originally developed for. One goal of sntools is to avoid such duplication of efforts in the future. We welcome contributions, preferably by opening pull requests or issues on the sntools GitHub repository.

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