SNEWS - The Supernova Early Warning System

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Abstract. The SuperNova Early Warning System is a cooperative project involving many experimenters coming from several, past and present, neutrino detectors. The primary goal of the collaboration is to provide the astronomical community with a prompt alert at the time of next galactic supernova. Requiring the online coincidence among neutrino detectors, world-wide distributed and with different detection techniques, SNEWS will generate a reliable, prompt and automated alert by eliminating the potential local false triggers.

In this paper I will give a concise overview on the project motivations, network implementation, working procedures and current status.

1. Introduction

Gravitational stellar collapses are astrophysical events of great interest. Because of the complexity of the problem, the modeling of the physical processes is still in evolution, but it is in general accepted that the role of neutrinos is critical to allow the supernova to form out of a collapse [1]. Moreover the confirmed detection (e.g. in [2], [3] and [4]) of the neutrino signal from the SN 1987A in the Large Magellanic Cloud marked the beginning of the neutrino astrophysics era. In spite of some unresolved controversies [5] the observation opened the way for a new method of investigation: the neutrino astronomy.

Even in the lack of a complete theory of the core collapse supernova explosion the correlated neutrino emission is believed to be well established and should be detected to maximize the scientific feed back with different active detectors when next event will occur within the Milky Way boundaries. More than 99% of the binding energy of the resulting neutron star is released in the form of $\nu/\bar{\nu}$ of all flavors at energy of tens of MeV, while the remaining 1% in the form of optically visible radiation and kinetic energy of the expanding remnant. The time scale of the neutrino emission is estimated few tens of seconds, promptly after the collapse, $\sim$ hours before the photon signal can emerge from the stellar envelope giving rise to the Type II supernova event.

A core collapse supernova in our Galaxy will bring therefore a wealth of scientific information. The early observation of the supernova light curve turn-on will bring informations about the progenitor and its environment, giving the astrophysicists the opportunity to learn more about the nature of the core collapse (e.g. the study of the explosion mechanism, black hole formation, accretion disks, explosive nucleo-synthesis) and, to particle physicists, valuable feed backs on neutrino properties themselves (e.g. absolute mass, mixing, magnetic moment).

The aim of SNEWS network is therefore to provide first the early warning of a supernova’s occurrence and second to improve global sensitivity to the neutrino burst via inter-experiment...
collaboration and downtime coordination.

2. The network strategy
From the experimental point of view any neutrino detector can provide its own supernova trigger but, usually, the warning generated by dedicated analysis gets hours, or even days, to be carefully checked. From experience a standalone of a positive observation announcement is a complicated and long job involving open discussions within experiment collaboration before any public release can be performed.

The idea of a blind central coincidence computer receiving signals from several experiments is the basis of the SNEWS network and, beyond the early warning advantages, includes many parallel benefits as: increased sensitivity to weak signals in the case of distant SuperNova (SN) event, suppression of non-Poissonian background fluctuations which are unlikely correlated in different laboratories and detectors, automated alert without any human interference and finally the possibility to determine, even with a poor resolution, the incoming direction.

To make the best use of a neutrino burst supernova alert we follow the astronomical community requirements summarized by the following three P -Prompt, Pointing, Positive- scheme.

- **Prompt** Time is mandatory for a supernova early warning and thus the alert must be as prompt as possible to catch the early stages of the shock breakout. We estimate a potential alert dissemination of minutes for the automated alert, depending on the expected delay in the alarm formation at each single detector. A timescale of 5 minutes or even less have been demonstrated during the commissioning phase of the network and is periodically checked out by using test signals.

- **Pointing** Clearly, the more accurately we can point to a core collapse event using neutrino information, the more likely it will be that early light turn-on will be observed by astronomers. Even for the common case when no directional information is available (e.g. for only scintillator detectors online) it is still useful for astronomers to know that a gravitational collapse event has occurred. However, any pointing information is extremely valuable. There are two ways of pointing with neutrinos: (1) individual detectors can make use of asymmetric reactions for which the products remember the direction of the incoming neutrino, tipically the $\nu_e$ scattering; (2) the timing of the neutrino burst via triangulation of signals recorded in different detectors around the globe.

- **Positive** It is clear that there must be no false supernova alerts to the world community. Requiring an inter-experiment coincidence the false alert rate can be decreased to nearly zero. We have chosen the nominal acceptable average false alert rate to be one per century, accordingly to the expected SN Type II event within the Milky Way boundaries.

When the emitted neutrino burst from a SN somewhere in the Milky Way will arrive at Earth the supernova monitor of each experiment forms the trigger and send it through a secure TCP/IP connection to the SNEWS server. If the server sees a $\geq$ 2-fold coincidence within 10 seconds, with at least 2 involved detectors at different laboratories, an automated supernova alert will be sent out by e-mail. This procedure eliminates the human time scale delay which affects procedure of verification by shifter and expert people at each single client detector. Sources of noise (i.e. electronic spikes, human errors, DAQ faults) that can mimic a SN real neutrino event are unlikely in coincidence at the same time at different laboratories, so far naturally
suppressed. The trigger logic is summarized in figure 1.

![Flowchart of the decision procedure to determine the type of the global alert dispatch](image)

**Figure 1.** Flowchart of the decision procedure to determine the type of the global alert dispatch whatever the type Gold, Silver or Individual. Details on the alert type definition and logic are fully discussed in [6].

Once the alert is generated a dispatch containing the essential informations (e.g. the involved detectors, the absolute time and, if available, the error box of the direction in the sky) is sent out via e-mail in order to join as many people as possible. That is why SNEWS maintains a mailing list of interested parties including professionals and amateurs to be alerted in the case of a positive signal. Any one interested can be freely sign-in at our central web site www.snews.bnl.gov. Amateurs astronomers are an integral part of SNEWS. They have wide area viewing capability, enthusiasm and expertise. In the absence of precise neutrino-driven pointing information, amateurs may be the first (as it was at time of SN1987A) to locate the supernova optical counterpart in the sky. Also the *Sky and Telescope* magazine manages an Astro-Alert mailing list to which the SNEWS dispatch will be automatically forwarded.

Details on the SNEWS network principles, adopted technical solutions and test results can be found in [6].

### 3. The SNEWS Status

Currently operating and contributing experiments to the alert network are Super-K [7], LVD [8], IceCube [9] and Borexino [10]. Two servers process client datagrams, i.e. the experiment alarms, the main one located at Brookhaven National Laboratory (BNL) and a second one at central data center of Istituto Nazionale di Fisica Nucleare (INFN) in Bologna, Italy. Only one server at time is enabled to dispatch the alert in case of a positive coincidence while both receive and process data from client detectors. For robustness of the system there are duplicate servers in both BNL and INFN hosting sites: they can be switched on if necessary. The time evolution of SNEWS (i.e. participating members and planned activities) is shown in
Figure 2. Status of the 12 years long story of the SNEWS project: past and present members are shown, being in automated alert mode online since July 2005.

Since July 1st 2005 the network is online with the automated alert mode enabled. We expect future experiments to join as they come online.

4. Conclusions
At present many running experiments are sensitive to the gravitational stellar collapses in the Galaxy looking to the neutrino signal and they make possible the early warning. Requiring the online coincidence among them a clear and automated real time alert will be provided by SNEWS. The network after a long commissioning and test phase comes to the effective automated mode in July 2005. Capabilities have been deeply investigated.
Up to day no signal has been recorded and we are still waiting for next supernova event in the Galaxy.

Acknowledgments
We would like to thank the members of the experimental collaborations for the help given to the SNEWS project development as well the responsible people at BNL and INFN Bologna laboratories for providing secure hosting sites and continuos maintenance of the coincidence servers.

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