Preparing to Observe the Next Galactic Supernova with IceCube and SNEWS

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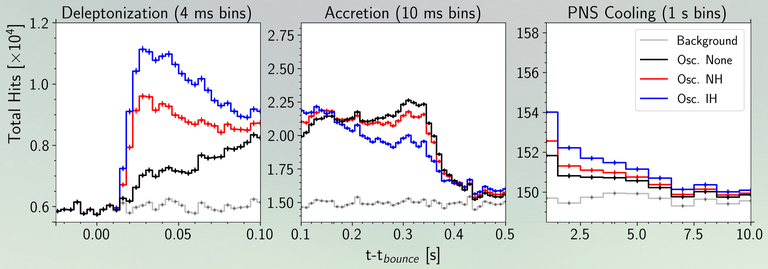
We present an overview of data challenges and "fire drills" used to ensure the readiness of the IceCube Neutrino Observatory [1] to observe the next galactic supernova.

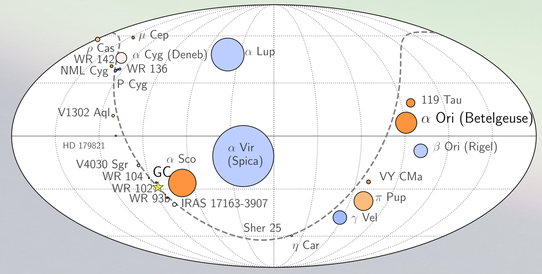
Motivation

The next galactic Core Collapse Supernovae (CCSN) presents the opportunity to make a groundbreaking multi-messenger measurement. The neutrinos emitted by such an event will probe both fundamental neutrino physics and astrophysics, including:

- Stellar core structure
- Stellar core equation of state
- Neutrino mass hierarchy
- Beyond Standard Model physics [2]



IceCube response to a 13 $M_\odot$ progenitor [3] at 10kpc assuming different neutrino mass hierarchies.



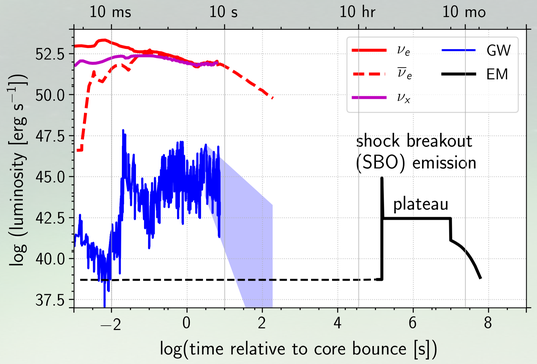
Galactic CCSN Candidates, marker size ∝ distance^{-2}.

Galactic CCSNe are quite rare (< 0.03 yr^{-1}), **so it is crucial to test the readiness of detectors and data pipelines in advance of such a unique event**.

[1] M. Aartsen et al. In: *JINST* 12 (2017), P03012. arXiv: 1612.05093 [astro-ph.IM].
[2] Segev BenZvi, Robert Cross, and Tri Nguyen. In: *PoS* ICRC2017 (2018), p. 892.
[3] Ken'ichiro Nakazato et al. In: *Astrophys. J. Suppl.* 205 (2013), p. 2. arXiv: 1210.6841 [astro-ph.HE].
[4] Ko Nakamura et al. In: *Mon. Not. Roy. Astron. Soc.* 461.3 (2016), pp. 3296–3313. arXiv: 1602.03028 [astro-ph.HE].
[5] F. Vissani, G. Pagliaroli, and F. Rossi-Torres. In: (2010). [Int. J. Mod. Phys.D20,1873(2011)]. arXiv: 1005.3682 [hep-ph].

The Multimessenger Bonanza

Neutrinos produced by a CCSN will arrive hours to days before any observable optical signal. Additionally, the observation of a neutrino signal could indicate the presence of a simultaneous gravitational wave signal.



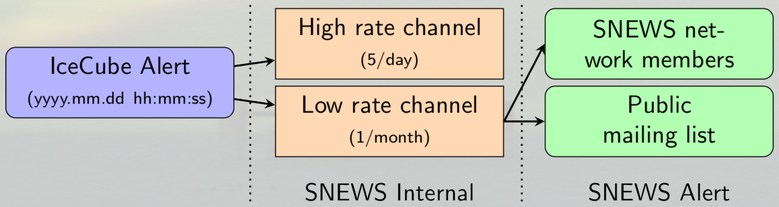
Luminosity of a CCSN in different cosmic messengers, adapted from [4].

Multi-messenger follow-up observations triggered by neutrino detection in a CCSN will provide complementary measurements such as:

- (GW) Measuring the absolute mass of the neutrino [5].
- (EM) first multiwavelength observations of the onset of the explosion.
- (EM) measuring the explosion's total energy and the progenitor's density profile.

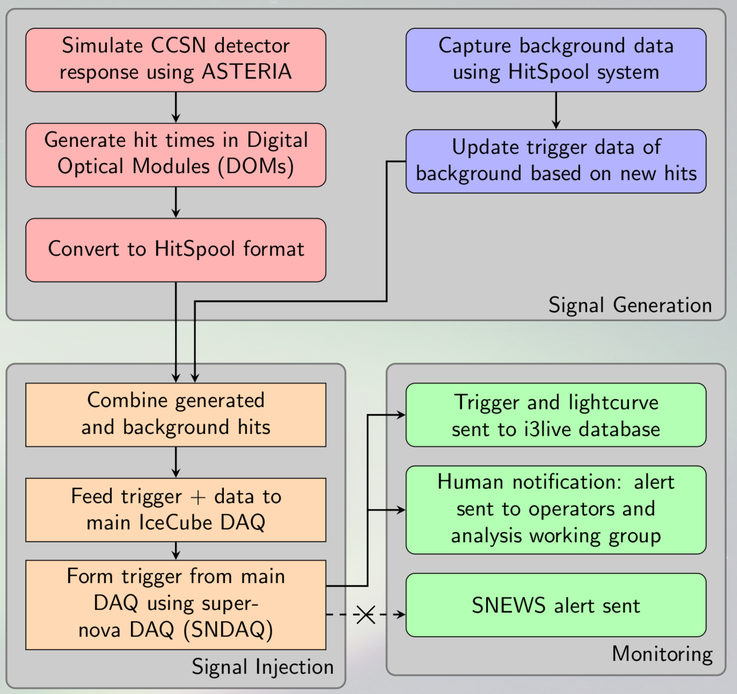
SuperNova Early Warning System

The SuperNova Early Warning System (SNEWS) is a multi-instrument CCSN neutrino detection network. IceCube provides a high-rate monitoring stream to SNEWS with ∼ 5 alerts per day. High-significance SNDAQ alerts ($> 8.4\sigma$ pre-trials) are sent roughly once per month.



Readiness: Supernova Fire Drills

Goal: Inject a simulated CCSN into the IceCube data stream:



Fire Drill Outlook and Extensions

IceCube is conducting "fire drills" to test its operational readiness for the next galactic CCSN. Preparation is crucial to ensure we do not miss these extremely rare events. Current and future tests include:

- Summer 2020: CCSN hit injection **offline** in the South Pole Testing System.
- Fall 2020: injection of hits into the **online** data stream for end-to-end readiness exercises.
- Winter 2021: **blind injection** ("fire drills") into IceCube online data stream.
- Spring 2021: integration of IceCube "fire drills" with SNEWS.

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