Recent Improvements in the Detection of Supernovae with the IceCube Observatory

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The IceCube neutrino observatory

- World’s largest $\nu$-detector monitoring 1 km$^3$ of Antarctic Ice
- 86 strings with 60 DOMs each
- Primary goal: Extraterrestrial neutrino point sources
- Supernova searches: Detect $\nu$ with O(10 MeV) energies by collective increase in dark rate
- Most precise detector for analyzing core collapse SN in our Galaxy

Non-Poissionian noise characteristics from HS data

- HitSpooling (HS): Buffers all PMT hits after external request
- Complete detector information available for SN candidates

Atmospheric muon hit subtraction

- $\text{Atm}$ with $E_{\mu} \approx 400$ GeV each detector and trigger if $E \approx 550$ GeV \rightarrow induced hits main background
- Correction method finds correlation between $R_{\text{hit}}^2$ and $\xi$ linearly (offset $a$, slope $b$)
- \[ \xi = \xi - b \cdot R_{\text{hit}}^2 - a \]
- Sample alert below:
  \[ \xi = 8.59 \rightarrow \xi' = 2.44 \]

Estimation of supernova direction

- No individual SN-$\nu$ interactions detectable due to O(10 MeV) energies
- $e^-$-direction uncorrelated to $\nu$-direction in inverse beta decay
- $\rightarrow$ determine direction from temporal hit pattern when neutrino wavefront abruptly change its intensity
- $\rightarrow$ Black Hole forming SN model
- Unbinned likelihood analysis using an optimised minimizer
- Reasonable directional resolution achievable only for close-by supernovae and low neutrino masses
- Potential improvement by deploying additional distant strings

Long term behavior of DOM dark rates

- Surprising observation: Average dark rate decrease by 3.3%
- 2% increased sensitivity to atm. $\mu$ $\rightarrow$ 50% more false positive alerts
- Triboluminescence (due to hole-ice freezing) suspected to emit the light

Future developments

- Assessment of sensitivity to the absolute neutrino mass
- Improvement of the energy determination
- Investigation of shorter bursts
- Extension of hitspooling to other use cases, e.g. the estimation of hadronic energy in highly energetic events from the delayed neutron capture signal