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The SuperNova Early Warning System (SNEWS)

The current network, and things to improve upon

SNEWS2.0 workshop
Friday June 14, 2019

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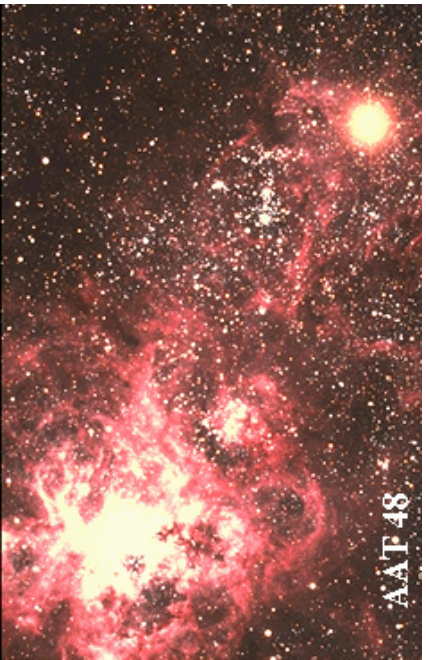
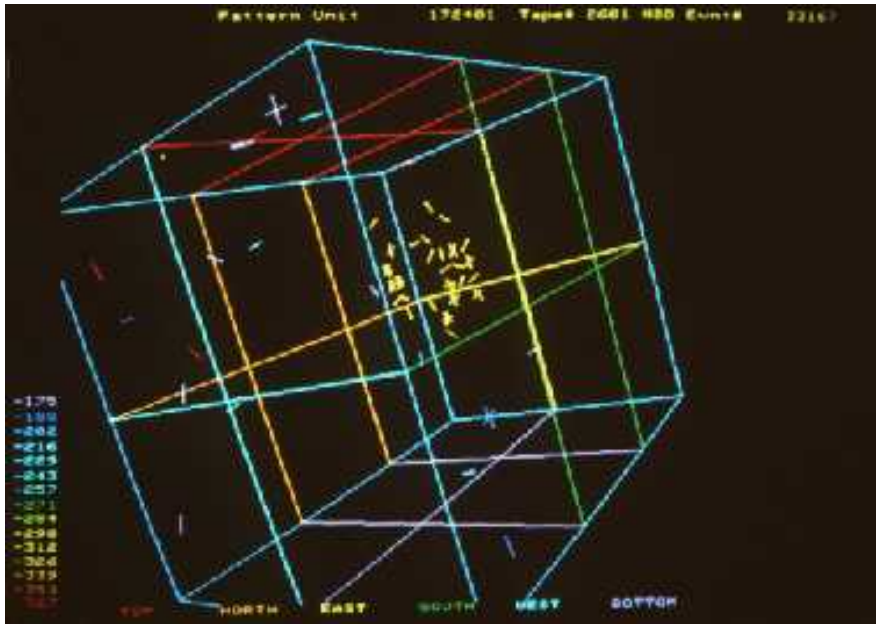
Origin Story

- At the neutrino meetings in 1996 (Helsinki) and 1998 (Takeyama), people were reminiscing about SN1987A and thinking about how we could do better in the future. This got Super-K, SNO, MACRO, and LVD together with John Bahcall.



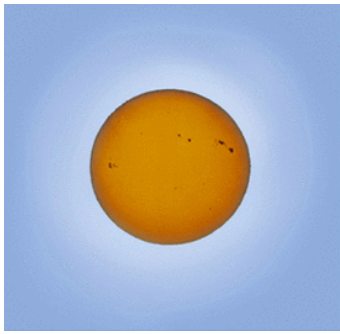
←Humans noticed this first…

… and dug this off tape later→



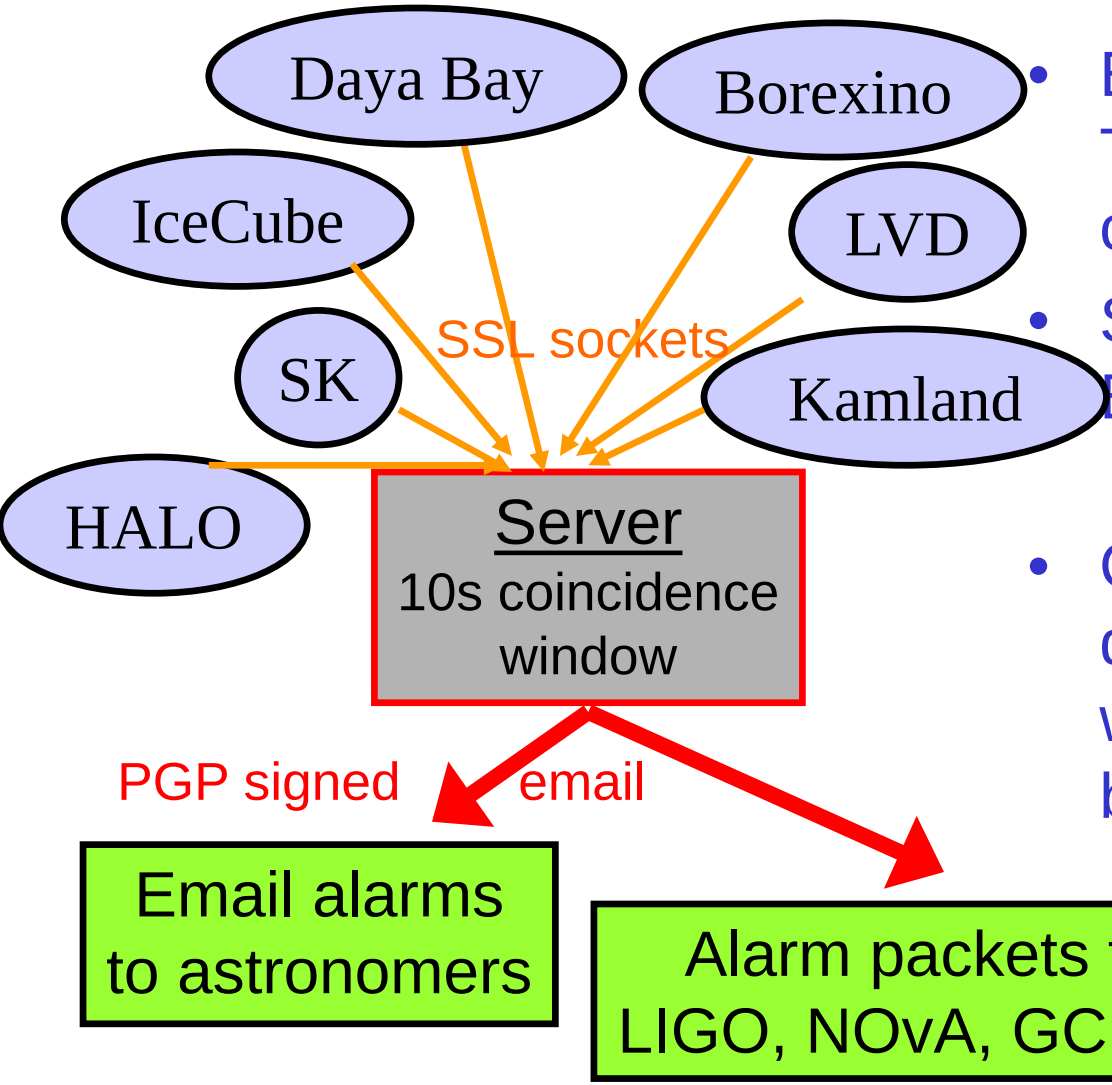
Despite ν arriving ~1.5h before the γ

Astrophysical and Human time scales



- ν lead the photons because stars are opaque to γ, but transparent to ν
  - γ are produced when the shock wave breaks through the photosphere, ~hours after core collapse
- Of course, each experiment had a SN ν trigger already to find a burst of ν
  - but routed the alarm through an on-call shifter to filter out false alarms from electronic noise, flashing PMTs, spallation by CRs, etc
  - Humans also take ~hour to weigh in
- But, two experiments will see the ν at the same time, and are unlikely to have coincident noise
  - Can we help provide an opportunity to experiments to go faster if they want to?

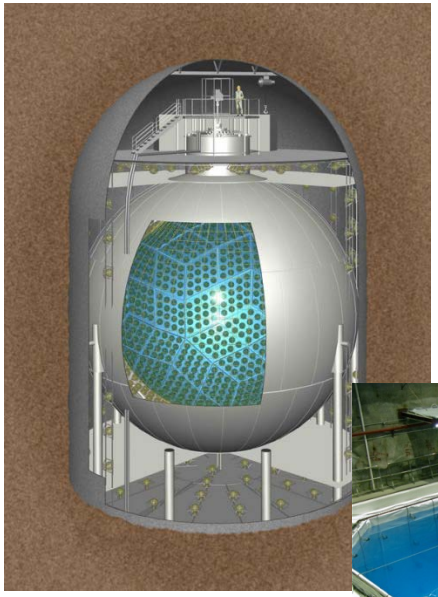
A Global Coincidence Trigger

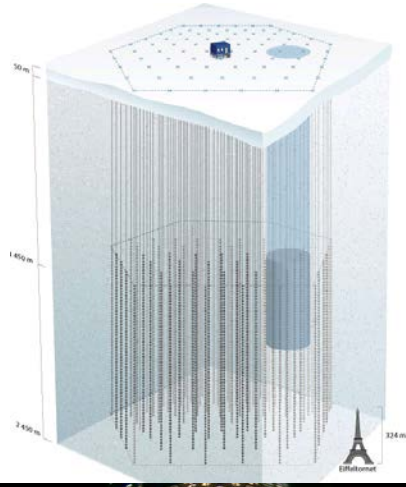


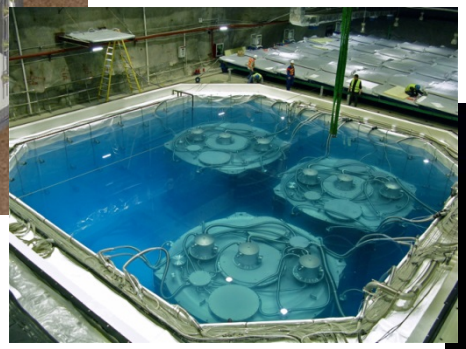
- Experiments send blind TCP/IP packets to central coincidence server
- Secure, stable hosting at Brookhaven
  - Backup server at Bologna
- Other benefits such as down time coordination, working relationship between SN teams, etc

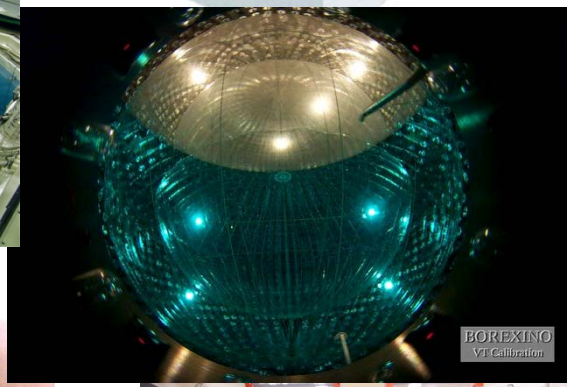
The Experiments

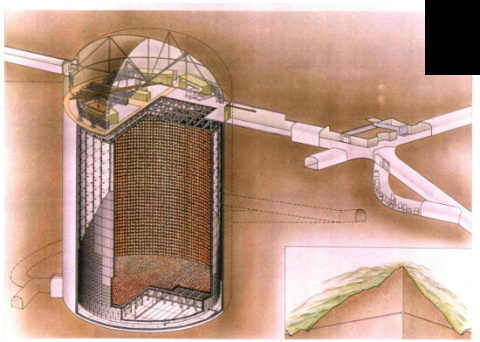
- Currently:
  - Super-K
  - LVD
  - IceCube
  - Borexino
  - Daya Bay
  - Kamland
  - HALO
- Alumni:
  - MACRO, SNO, AMANDA
- Operational but not SNEWS contributors:
  - Baksan, μBoone
- Near-Future participants
  - NOvA, Km3Net, SNO+

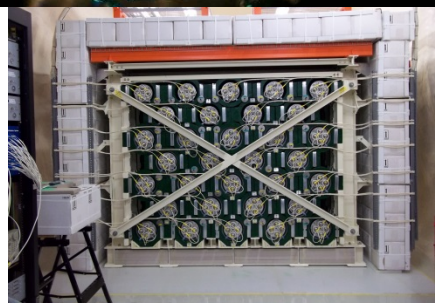






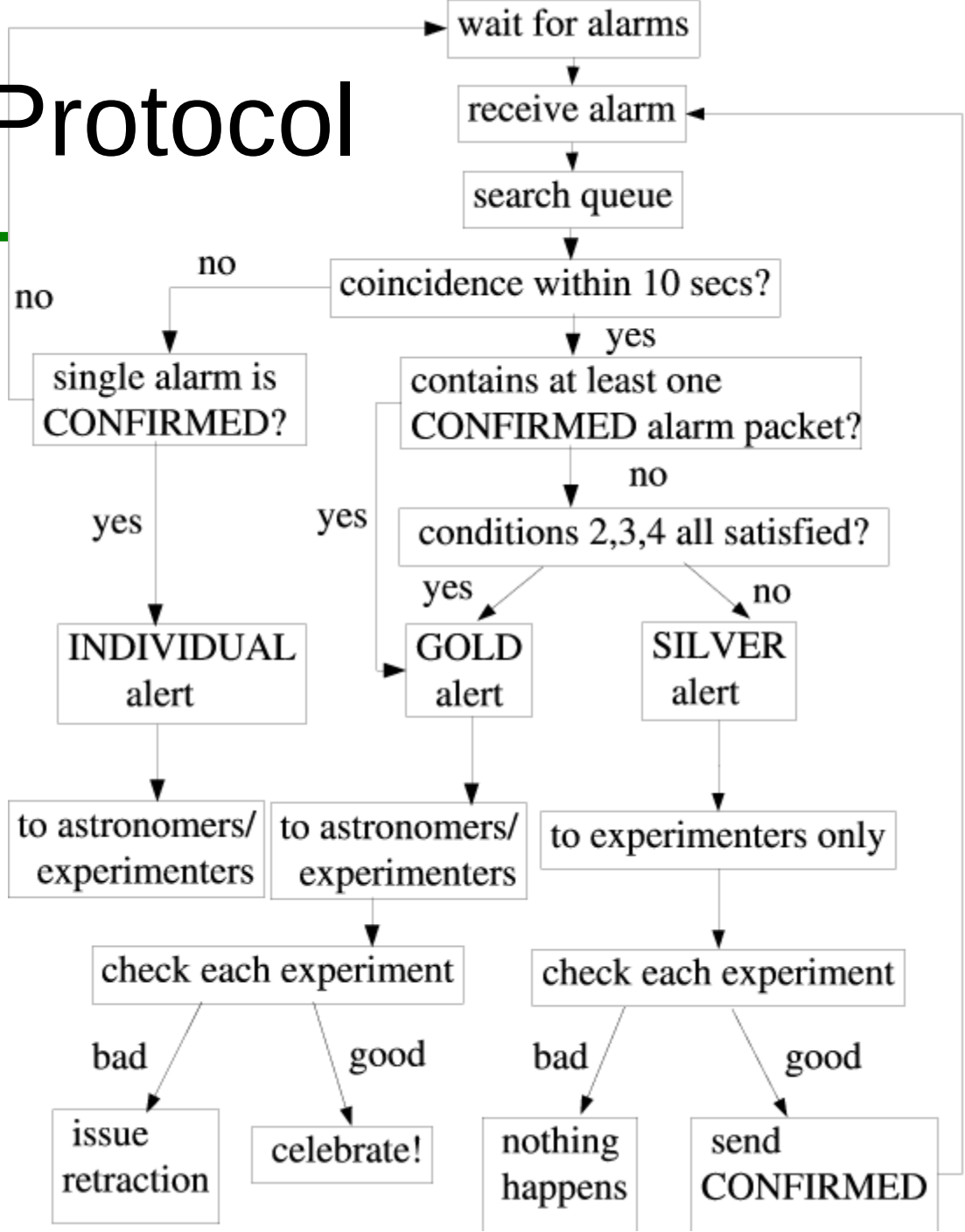






Alarm Protocol

- A “simple” coincidence…
- What the coincidence server really does
  - To minimize risks of false alarm, while maximizing the chances of getting the (right!) word out
- Experiments can also utilize SNEWS to send their own human-confirmed alarms to the world



SNEWS' Goals

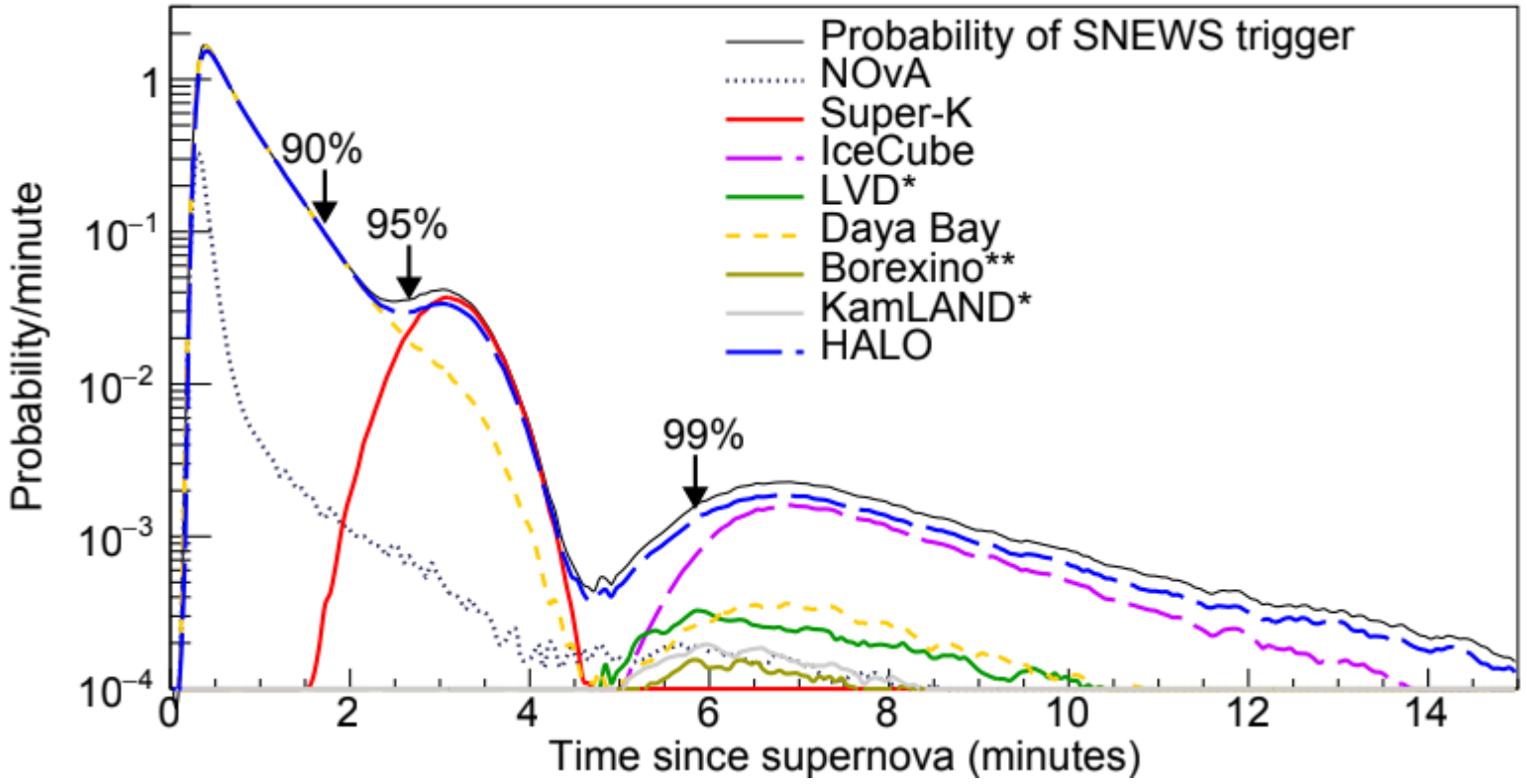
- At a workshop in Sept. 1998 at Boston U., neutrino physicists and astronomers came up with design goals: the "Three P's":
  - Prompt (<< 1 hour)
  - Positive (false alarms < 1/century)
  - Pointing
- Why?
- How well have we done in the nearly two decades we've been doing this?
  - Operational in test mode since 2001, fully operational July 1, 2005
- Should these goals change for the future?

Prompt

- Caveat: we have had no SNe in/near our galaxy since 1987: so SNEWS has never triggered
  - Something which confuses some fraction of the 6,190 snews-alert subscribers when they subscribe but then don't get alerts!
- What do we expect? Given a two-fold coincidence, the fastest two experiments to report set the delay
  - The SNEWS machinery itself responds in ~seconds

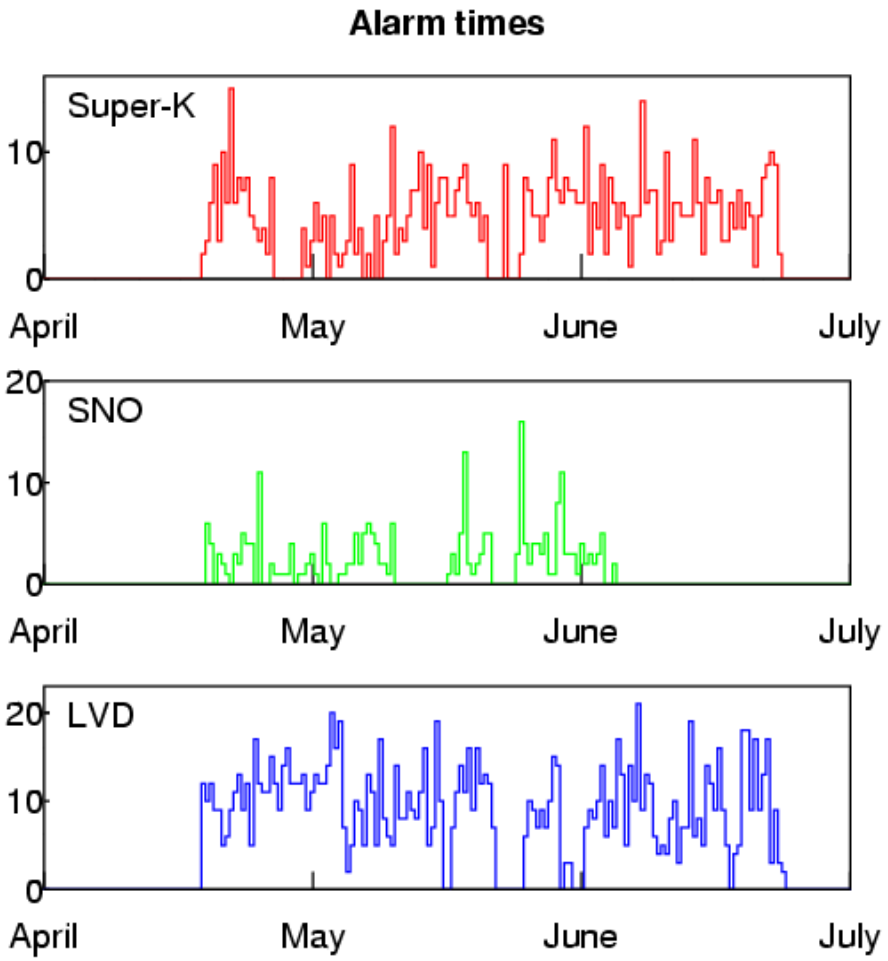
Estimated delay

- Matt Strait (UofM) took published SN trigger delays combined with sensitivities, estimated SNEWS response time
  - NOvA triggers on SNEWS but has a limited buffer time



Prompt?

- We think so, within minutes
  - Faster would be better: *eg*, unraveling the mysteries of GRBs became possible when followups could happen within seconds
- We don't know so: aside from a "high rate test" in 2001 (*low thresholds, triggered on noise*) the machinery doesn't get exercised
  - *eg*, recent LIGO GW alerts started off with more delay than desired, as kinks were worked out with practice

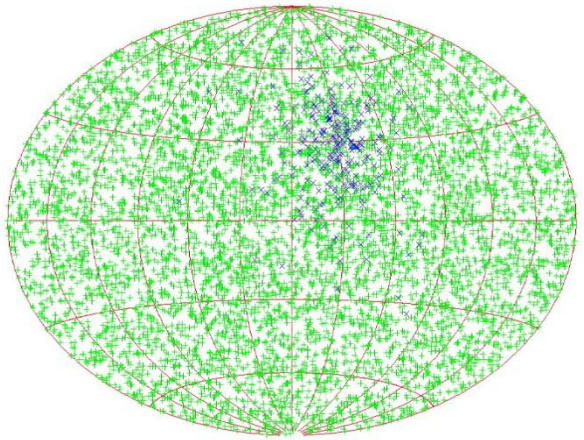


Positive?

- No false alarms in two decades! (*knock on wood…*)
- The flip side is that we haven't had the full test of the pipeline which alarms (*false or otherwise*) would provide
  - 2001 high rate test exercised front end
  - 2003 "find Vesta" test exercised the back end
- What astronomers want has flipped 180^{o} in those two decades:
  - 2000: "If you have even one false alarm, no one will ever believe you again"
  - Today: "Multi-messenger astronomy generates oodles of alerts, no problem!"

Pointing?

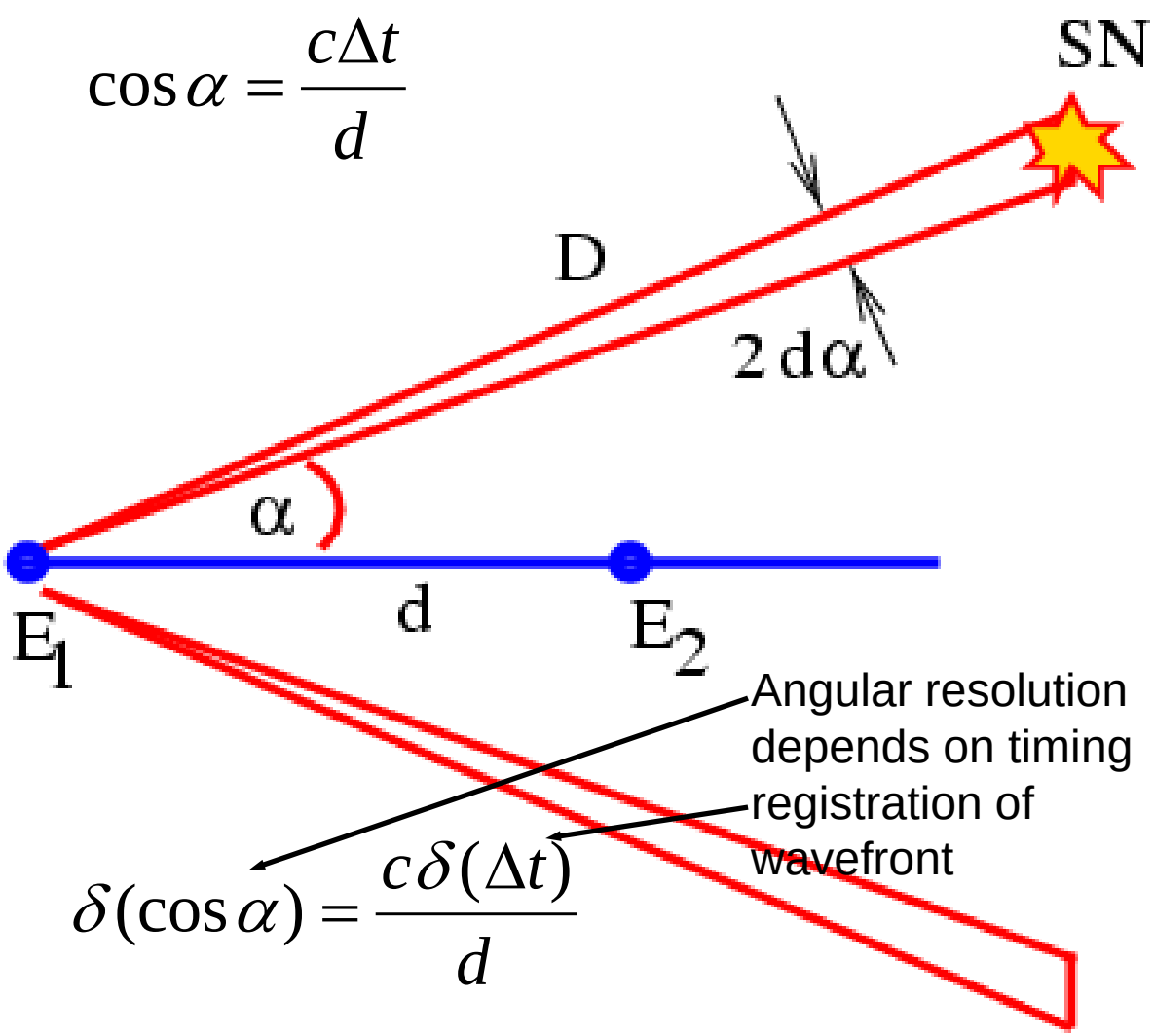
- SNEWS cannot generate directionality on its own
- Super-K can point back to within ~4º using the sub-dominant electron elastic scatters
  - and will do this even better once Gd n captures tag IBD interactions



- Timing triangulation killed by statistics of leading edge of signal
  - Beacom&Vogel, astro-ph/9811350
  - … or, is it?

Triangulation

$$\cos\alpha = \frac{c\Delta t}{d}$$



- Look at arrival time difference of SN ν wavefront at different detectors
  - With 2 expts, circle on sky at angle α
  - 3 expts – 2 blobs
  - 4 expts – 1 point
- With modern detectors, and fitting the whole ν light curve rather than just the leading edge, this might now be possible

Improvements for SNEWS 2.0

- What can we do to update SNEWS to provide:
  - Multiple thresholds, to constantly exercise the machinery and to provide consumers with a “choose your own threshold” alert
  - Ability of experiments to compare ν “light curves” real-time, to extract physics quickly: especially precision timing for triangulation
  - Get alerts out to the new networks, to best coordinate with modern multi-messenger networks

New Physics for SNEWS 2.0

- Pre-supernova (*Si-burning*) ν from nearby stars:
  - Kamland does this now on its own
  - SNO+ and JUNO will soon be able to as well, as can Super-K with Gd loading
  - This is an area where combining low statistics could let these experiments expand their range further into the galaxy
- Pointing:
  - DUNE and Hyper-K will have per-event directionality
  - SK will improve theirs with Gd tagging
  - Maybe SNEWS can contribute triangulation
  - A new opportunity to provide directionality combination for those experiments?

Tools needed

- The simple coincidence riding on the network protocol stolen from the first “e-sports” game ever (*netrek, early 1990’s*) can’t support these new goals (*and you wouldn’t want to maintain it anyway*)
- What statistics are the best to compare experiments with extremely different signal rates and noise rates?
- What machinery is needed to reliably move that data from experiment to a SNEWS server?

Experimental Expertise

- Whatever information a SNEWS server is consuming will need to be turned into something fairly “detector independent” by the experiments
  - So we’re comparing apples to apples
- This requires a lot more work from an experiment than simply sending SNEWS a “saw a supernova!” timestamp
  - Work that can only be done by someone with a deep understanding of that particular detector

White Paper

- Getting the information and plans discussed in this workshop into a white paper is a goal of this workshop
  - Goal: end of summer
- Topical working groups will tackle specific sections
- The panel discussions are hoped to be the seed for this

- Whitepaper outline and very rough draft exists

Contents

Summary

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- While one of the ~200 SNe ν wavefronts currently traversing our galaxy hasn't arrived since 2000, we've been ready with a simple coincidence trigger
- Experimental capabilities have evolved
- Real-time multi-messenger astronomy is now a thing
- Let's figure out how to get the world the most SN neutrino information in the least amount of time
  - An opportunity for gaining information that together is greater than the sum of its parts

Acknowledgements

- SNEWS currently supported by NSF collaborative grant #1505960
  - Alec Habig @ UofM Duluth
  - Kate Scholberg @ Duke
- SNEWS only functions with the cooperation of member experiments and their SN teams, Brookhaven, and INFN Bologna
- New NSF *Windows on the Universe* award “A Next-Generation SuperNova Early Warning System for Multimessenger Astronomy” will be to Purdue, Duke, Duluth, MIT, Houston, Rochester, Laurentian, and Virginia Tech: Proposal PHY-1914448