SNEWS

The Supernova Early Warning System

of

Exploding Stars,

Weakly-Interacting Particles,

and Being Prepared

20 Years After SN1987A

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for the SNEWS working group

Small Δt SN Observations

SN1987A

Blue Giant
Sk -69 202

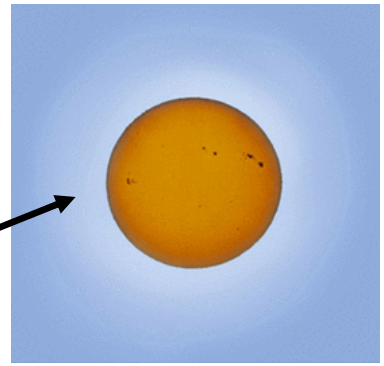
- Earliest observations (and non-observations) of SN1987a were fortuitous
  - ~hours before/after the actual event
  - Chance observations (Shelton, Duhalde, Jones)
  - Very careful observer records null-observations to constrain breakout time (Jones)
- Extragalactic SNe not so obvious
  - Typically days-weeks elapse before someone notices
- What goes on between these pictures?

The Scheme

- Now that we know we can see SN ν, how to do it differently the next time?
  - (*caveat – nearby only, from Milky Way and environs*)
- "Luck" = Opportunity x Preparation
  - Neutrinos are emitted promptly upon core collapse
  - Produce obvious signal in today's detectors, most have automated analysis chain to trigger on SN ν
  - Instant information transfer now commonplace
  - A galactic SN would be close enough we'd really want to have very good observations starting at t=0
    - *ie*, we'd have a prayer of *noticing* whatever cool things happen at or shortly after breakout
- So let's trigger photon-based observations of the next galactic SN using the neutrino pulse

Advance Warning

- Observations from t=0?
  - Sure. Or very nearly so, certainly better than the serendipitous ~hours of SN1987A, and far closer than the ~days which is the best we can get on an extragalactic SN



- How?
  - ν's exit the SN promptly
  - But stars are opaque to photons
  - EM radiation is not released till the shock wave breaks out through the photosphere – a shock wave travel time over a stellar radius
  - ~hour for compact blue progenitors, ~10 hours for distended red supergiants

Tomorrow?

- Humans haven't seen a galactic SN since Kepler, why bother looking?

Mean interval (yr) per galaxy	Core Collapse	All SNe
Historic Visible	?	30-60
Extragalactic	35-60	30-50
Radio Remnants		<18-42
γ-ray remnants		16-25
pulsars	4-120	
Fe abundance	>19	>16
Stellar death rates	20-125	

Overall?

3±1 per century!

(only ~1/6 of that if you insist on unobscured optical photons)

Academically –
one per career,
if Monsieur Poisson cooperates

Is This Practical?

- The neutrino experiments must be able to:
  - Identify a SN ν signal
  - Confirm it's not noise
  - Get the word out
  - Figure out where people should be pointing
  - All in an hour
- Note that the GCN/Bacodine network does this in seconds for Gamma Ray Bursts
  - Although they have a specialized circumstance and a lot of practice

Why a Network?

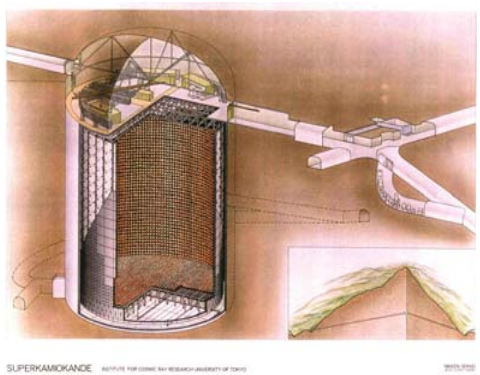
- Any given experiment has their own SN ν trigger, analysis, different strengths, weaknesses, etc
- So why band together?
  - The warning gets us hours ahead of the game
  - From experience, a human verifying an alarm takes ~hour
  - Experimental techniques often complementary
- That's a wash. Need to eliminate the human link to regain the "Early" in the "Warning"
  - Automation!

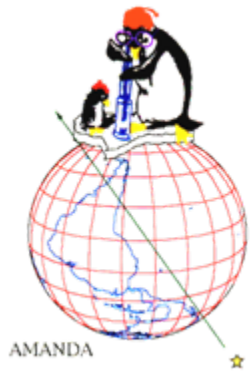
Automation?

- SNEWS
  - Supernova Early Warning System
- Any single experiment has many sources of noise and few SNe
  - Flashing PMTs, light leaks
  - Electronic noise
  - Spallation
  - Coincident radioactivity
- Most can be eliminated by human examination (takes time)
  - No experiment would want to make an automated SN announcement alone!
- None will simultaneously occur in some other experiment

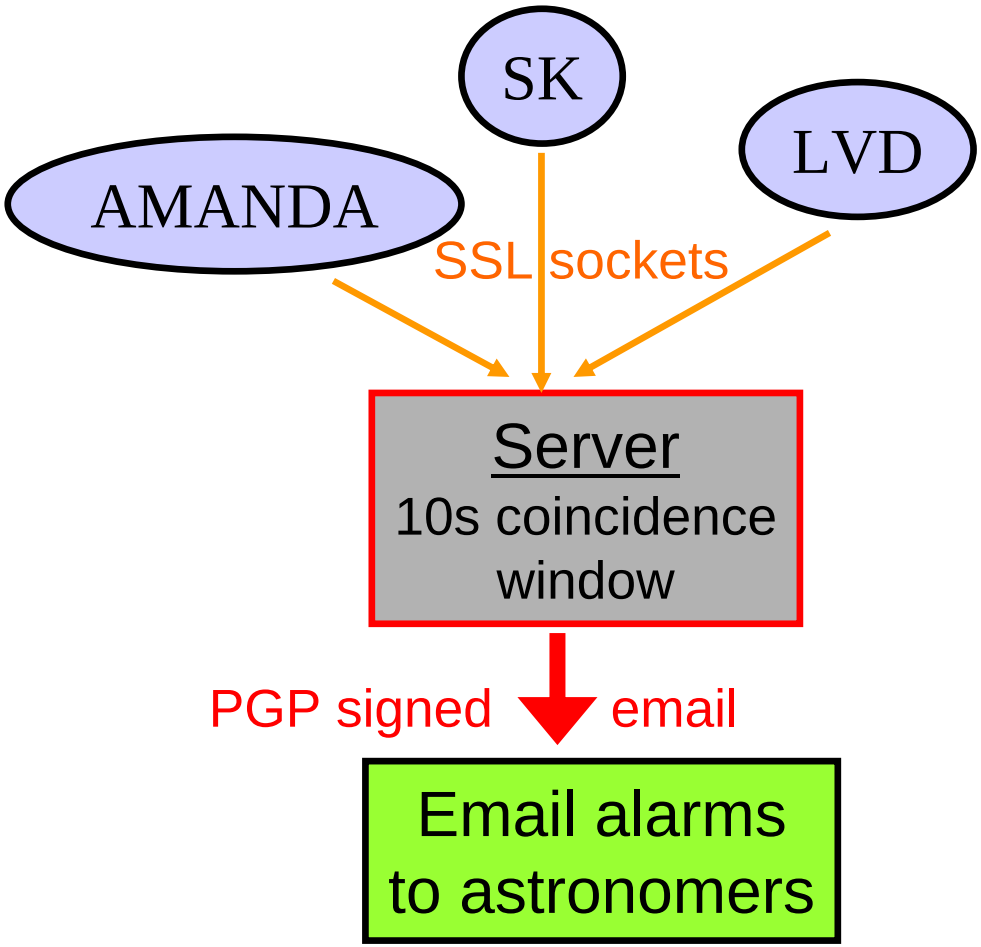
The Experiments

- Currently:
  - Super-K
  - LVD
  - AMANDA
- Alumni:
  - MACRO, SNO
- Operational but not SNEWS contributors:
  - Baksan, KamLAND, MiniBOONE
- Near-Future participants:
  - Ice Cube, Borexino, Daya Bay, NOVA, SNO+, HALO





A Global Coincidence Trigger



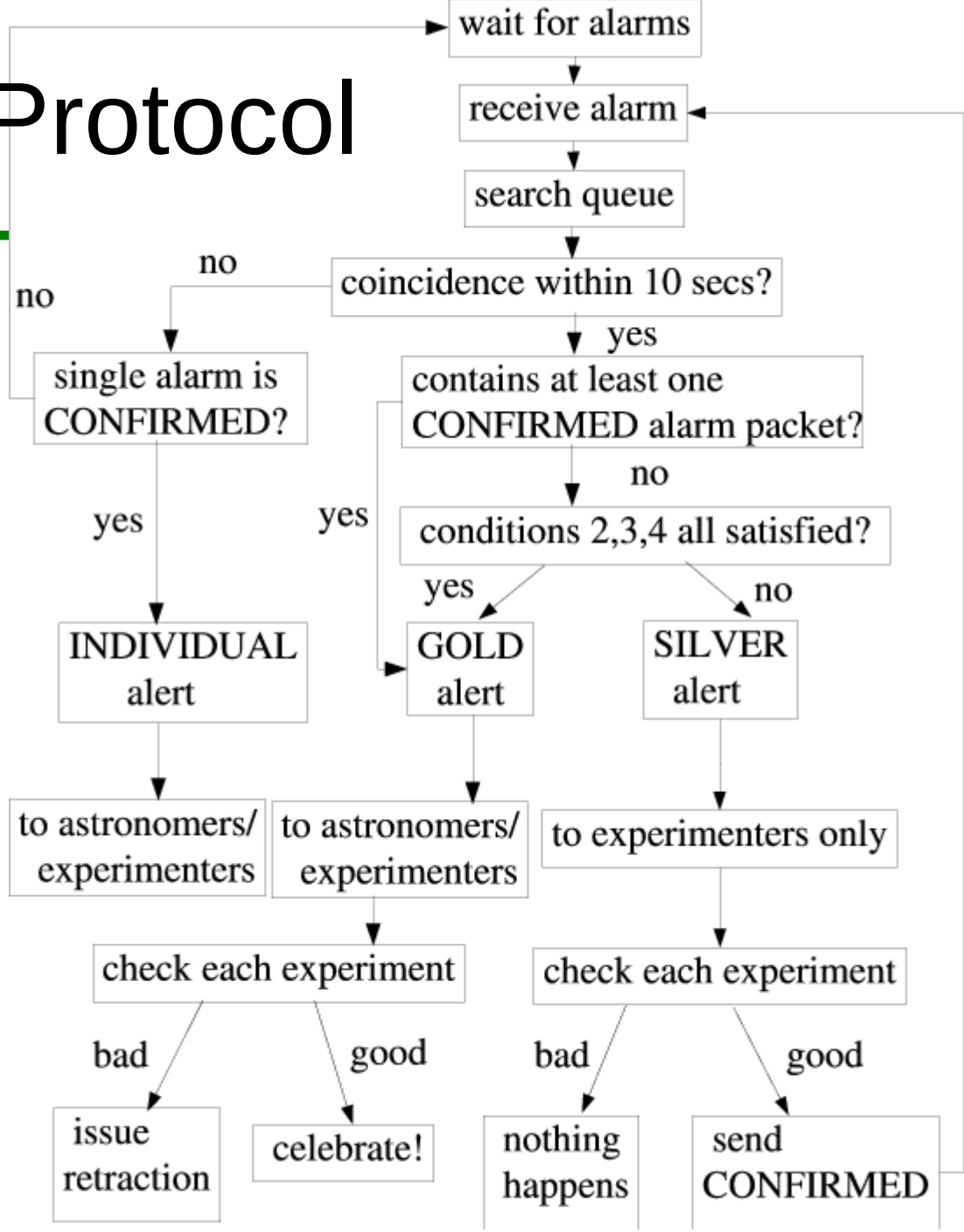
- Experiments send blind TCP/IP packets to central coincidence server
- Secure, stable hosting at Brookhaven
  - Backup server at Bologna
- Other benefits such as down time coordination, working relationship between SN teams, etc

Alarm Quality

- Experiments tag alarms with their quality estimate, SNEWS applies logical OR to produce an alert
- SNEWS will produce one of two results in event of a time coincidence:
  - "Gold"
    - Go out and look up! Automated alert sent
  - "Silver"
    - Experiment self-flags input as Questionable data quality
      - *eg* calibrations, marginal signal
    - Experiment in question has been noisy, two at same lab and nowhere else, etc
    - Sent only internally, to participating ν experiments
      - Can be upgraded to gold after human check

Alarm Protocol

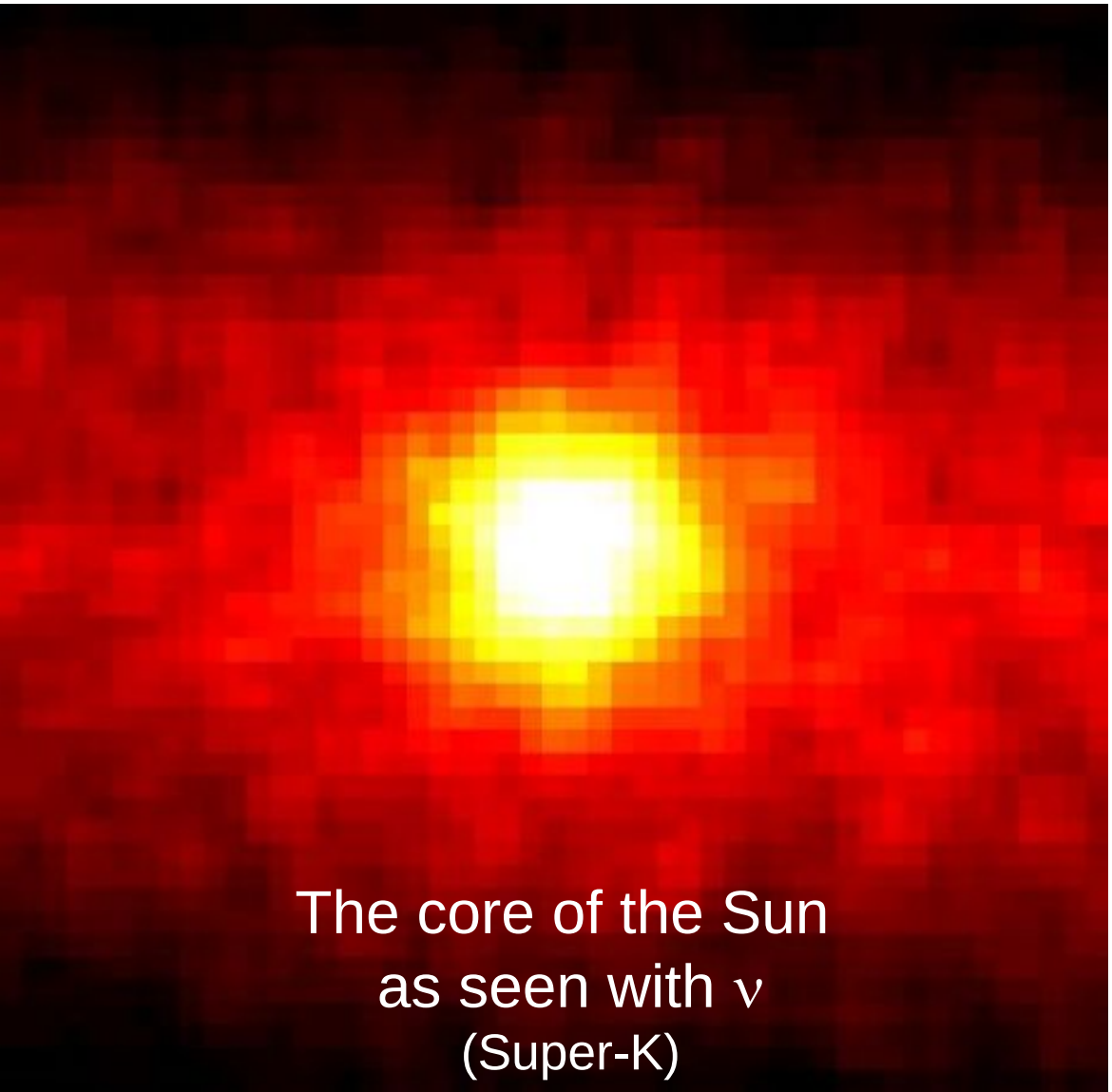
- What the coincidence server really does
  - To minimize risks of false alarm, while maximizing the chances of getting the (right!) word out
- Experiments can also utilize SNEWS to send their own human-confirmed alarms to the world



Quick, reliable, but information free?

- We have been working on “The Three P’s”:
  - Prompt (<< 1 hour)
  - Positive (false alarms < 1/century)
  - Pointing
- An ideal alarm would be “Look at Betelgeuse, it’s about to blow!”
- What directionality can neutrinos provide?
  - Elastic Scattering $\nu_x + e^- \rightarrow \nu_x + e^-$
    - Cone of 4.5^o from SK (for galactic center SN)
    - (Cone of 15^o from SNO, but it’s off now)
  - $\bar{\nu}_e$ CC weak asymmetry, also ^{2}H breakup
    - tenths of $\cos\theta$ at best

Elastic Scattering



The core of the Sun as seen with ν (Super-K)

- This is the reaction that lets Super-K identify solar neutrinos
- Problem – each pixel in this picture is about 0.5^{o}
  - Diameter of full moon
- Resolution dominated by neutrino/lepton scattering angle not experimental resolution
  - Can't upgrade that

Pointing?

- Looks like we are limited to ~100 square degrees at best
  - Ok for Schmidt cameras, not so hot for detailed work
  - Keep shooting starfields and sort it out later?
- Where to from here?
  - Amateur network of many skilled eyeballs! (see next talk)
  - Once someone optically ID's the new SN, we all know and can zoom in
- High energy transient satellites will also provide rapid localization
  - Shock breakout through photosphere produced UV flash in 1987A, should be lots of high energy fireworks given today's fleet of high-energy orbital telescopes
- LIGO can trigger on (direction-free) SNEWS alert, save more GW data that it would otherwise

Using the Alert

- The resulting coincidence alert goes to:
  - Email list of interested people
    - Sign up for alert email, http://snews.bnl.gov
  - VOEvent network/GCN
    - Since photosphere breakout should really light up the high energy photon sky
  - S&T's AstroAlert service (see Rick's talk next!)
  - LIGO
- What cool stuff with a once-in-a-lifetime nearby supernova would you like to learn?
  - Progenitor status?
  - Shockwave blowing through stellar system?
  - Stellar wind just before the end?
- Data you couldn't take after the fact!
  - From a time window no-one's ever seen

Summary

- A core-collapse SN will occur in our galaxy sooner or later
  - A once-in-a-career chance to study something that's never been studied before up close
- It will produce a ν signal ~hours in advance of the light
  - Early Warning!
- Pointing not great until someone sees it with photons
  - But even with no pointing, the time is well spent waking up, getting logged in, to the observatory, etc.
- What would you like to learn from early light?
  - *or…* what could your experiment do to maximize the chances of catching it?

Acknowledgements

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- SNEWS only functions with the cooperation of member experiments and their SN teams, plus *Sky & Telescope*, Brookhaven, and INFN Bologna

- See http://snews.bnl.gov for more info and to sign up for the alert list