Part I: The SuperNova Early Warning System

Part II: Next tutorial: Making a MC Tuning Sample

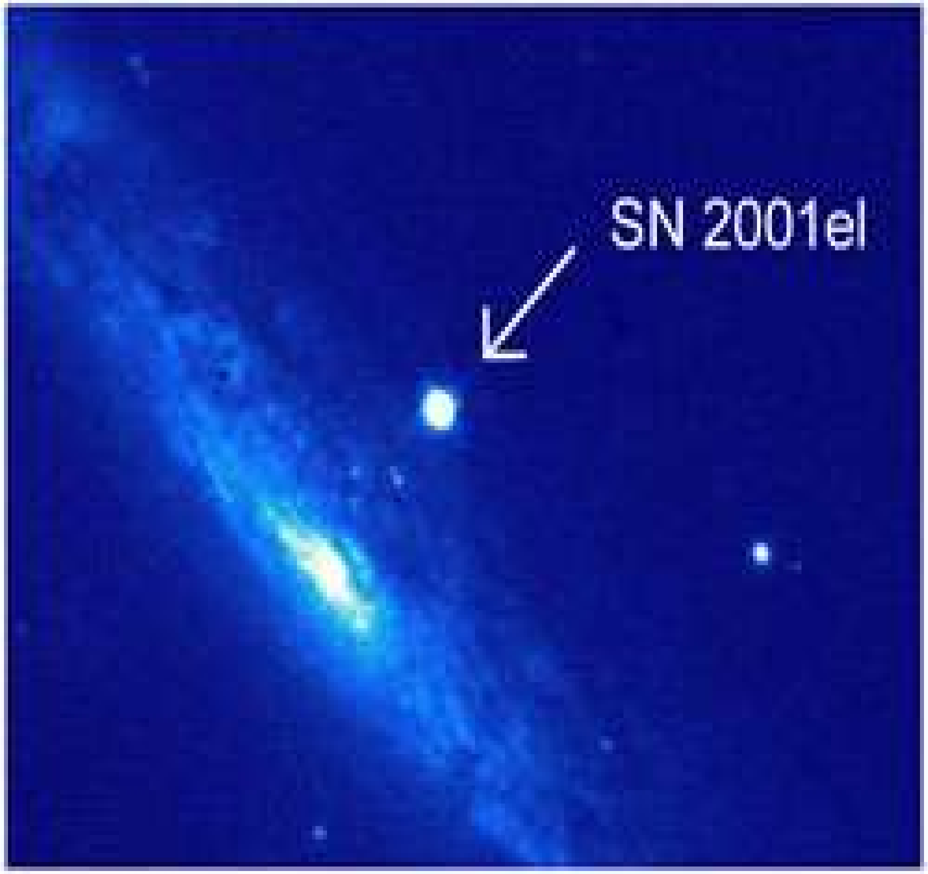
I will email you with projects within a week or so

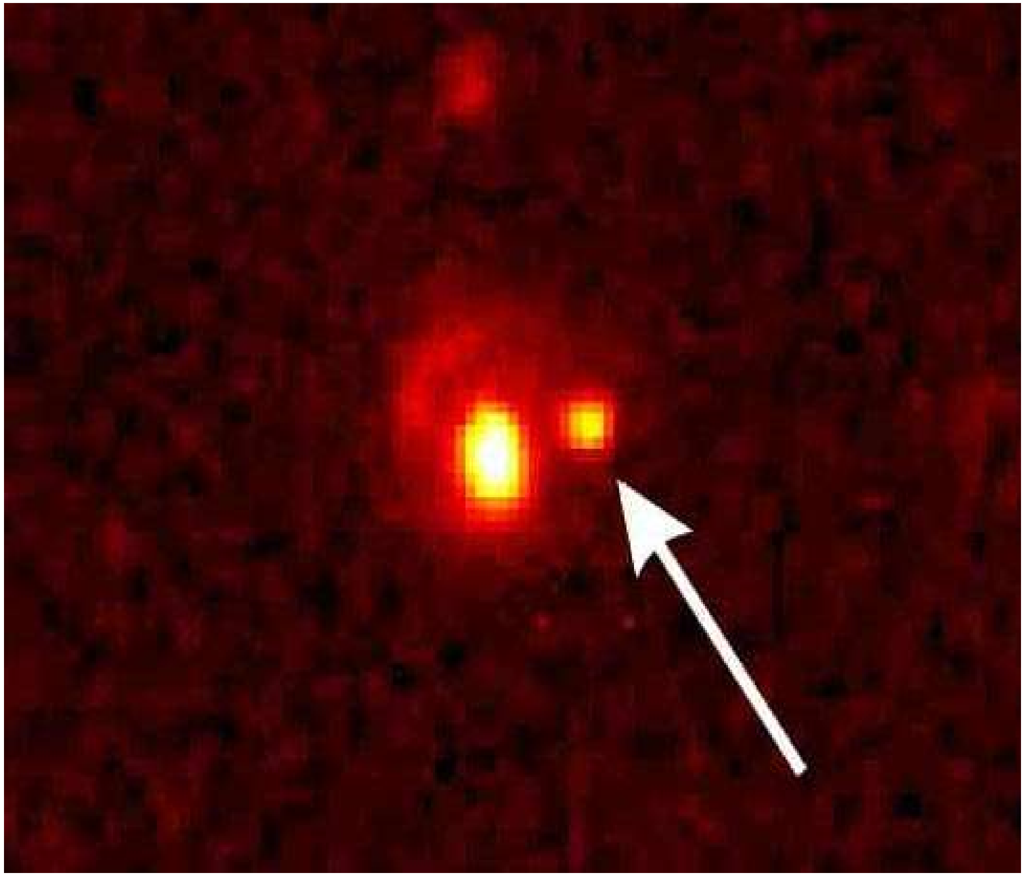
SNEWS

The SuperNova Early Warning System

Supernovae

Supernova: An energetic outburst resulting in the disruption of a star





For a while, as luminous as a galaxy!

Supernova Mechanisms

Identified by

- spectra
- light curves

Type Ia

no H lines

<u>**Model**</u>**: white dwarf accretes matter from companion**

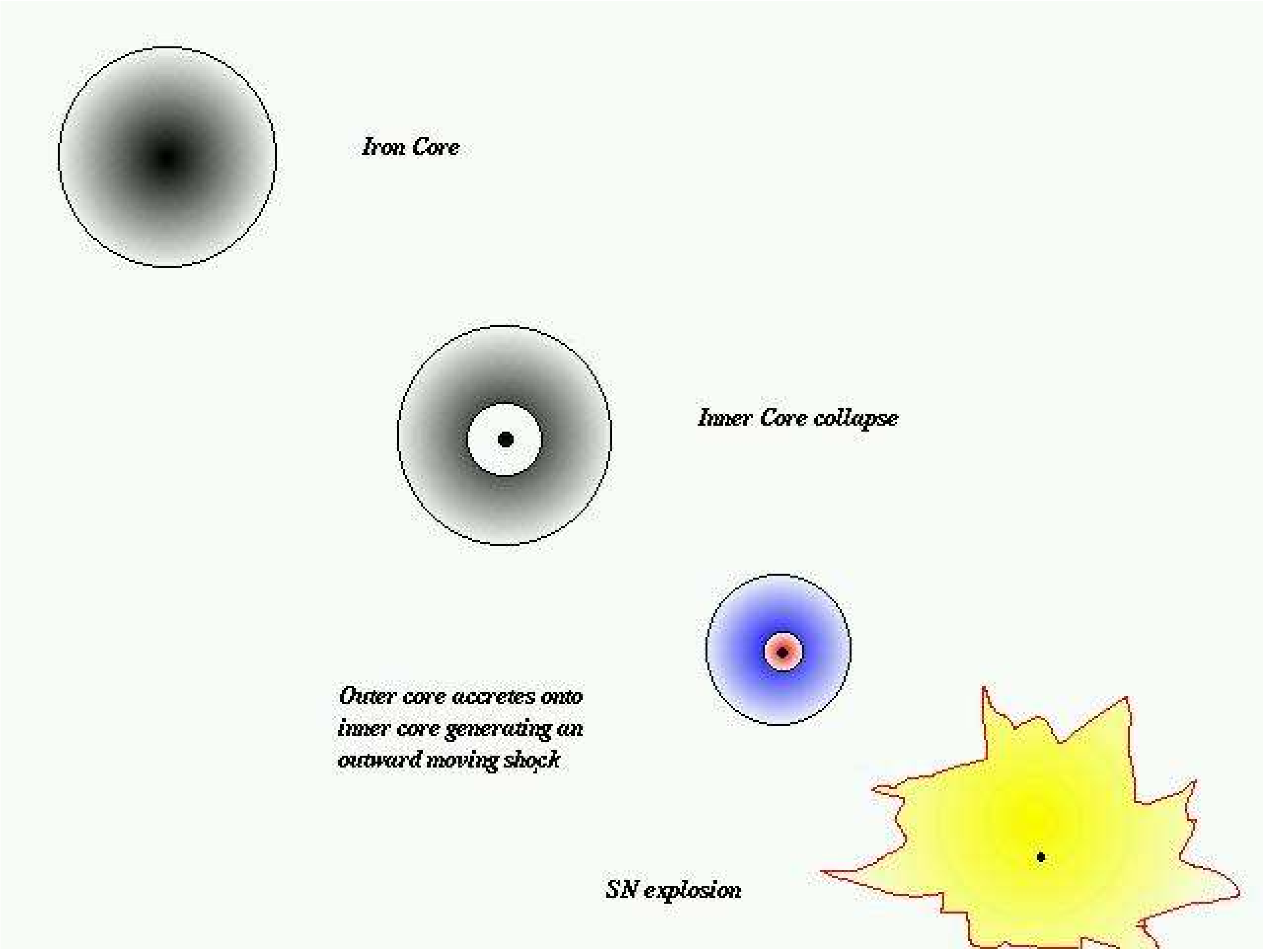
→ *thermonuclear explosion* when critical mass reached

Type II

H lines present

<u>Model</u>: ***gravitational collapse*** **of a massive star at the end of its life**

Copious producers of neutrinos!



How Often Does a Galactic Core Collapse Occur?

Estimates vary...

	Mean interval (yr)	
	Core collapse	All SNae
Visible SNae in history		30-60
Extragalactic SNae	35-60	30-50
Radio remnants		<18-42
γ-ray remnants		16-25
Pulsars	4-120	
Iron abundance	>19	>16
Stellar death rates	20-125	

Overall, can expect **3±1 per century**

Neutrinos from Supernovae

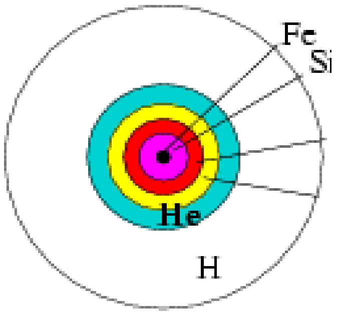
>99% of the energy from the supernova is in the form of neutrinos!

< 1% of the energy is in the form of photons and kinetic energy

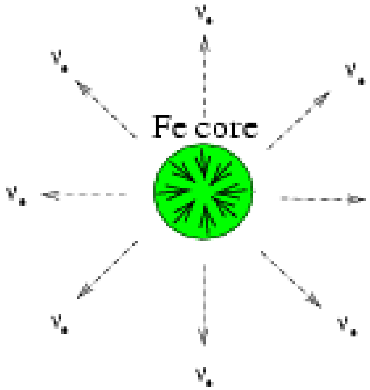
Most neutrinos are emitted over about *10 seconds, promptly after core collapse*

PRE-SUPERNOVA

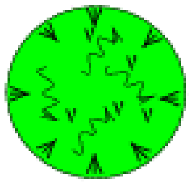
"onion-skin"



CORE INFALL

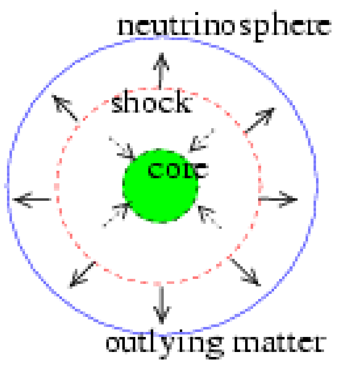


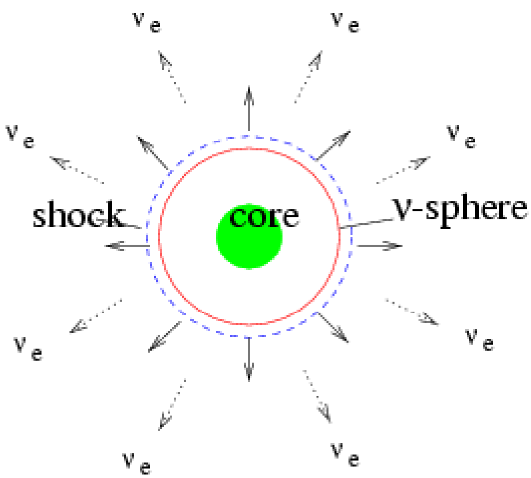
NEUTRINO TRAPPING



CORE BOUNCE

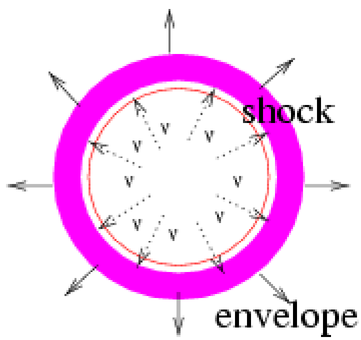
shock formation





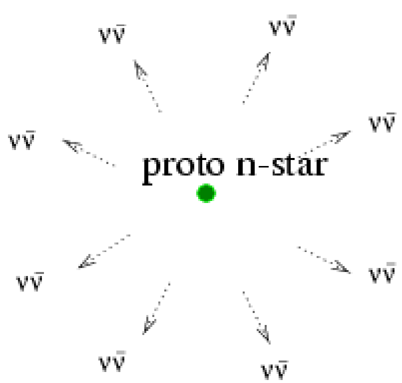
NEUTRINO "BREAKOUT"

Within milliseconds of collapse



EXPLOSION

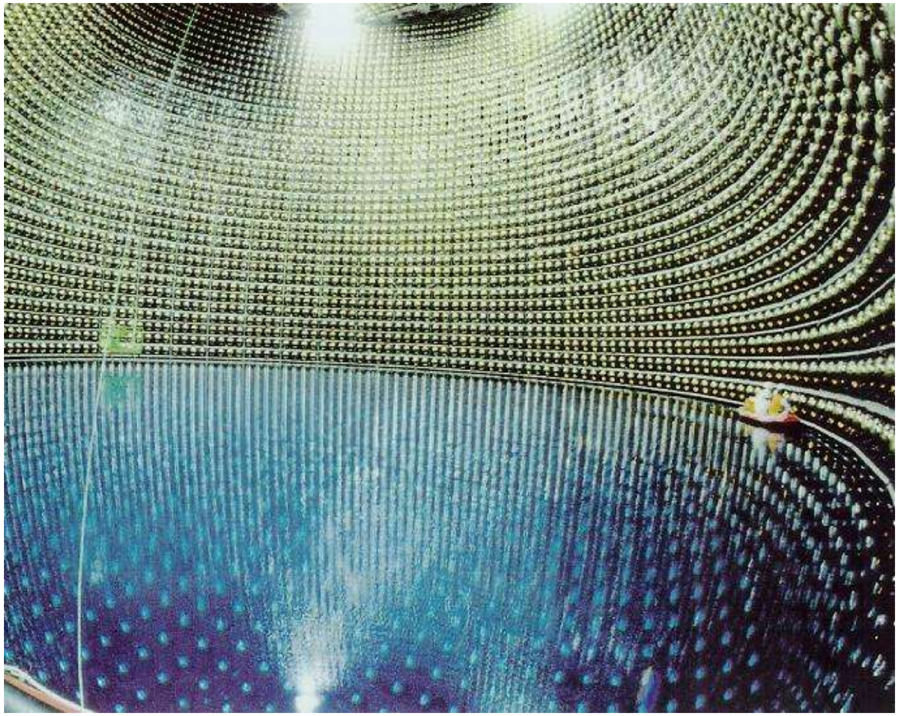
star disrupted (or fizzles...)



COOLING

energy shed via neutrinos, over tens of seconds

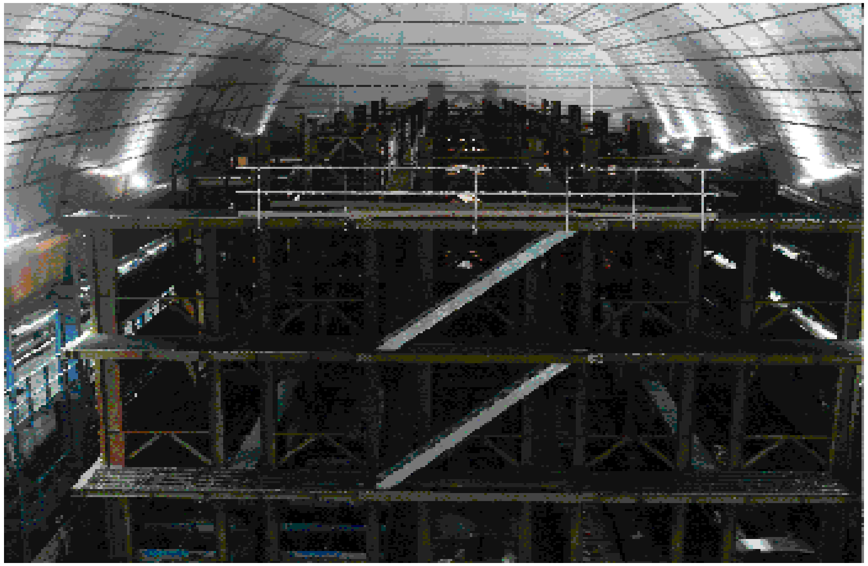
Visible aftermath after ~hours or days



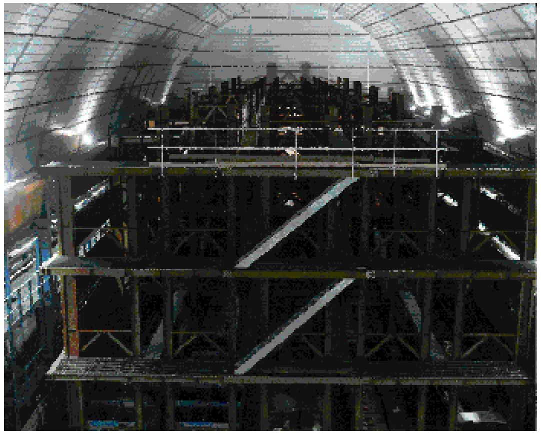
Need **HUGE** detectors (at least kilotons of material)

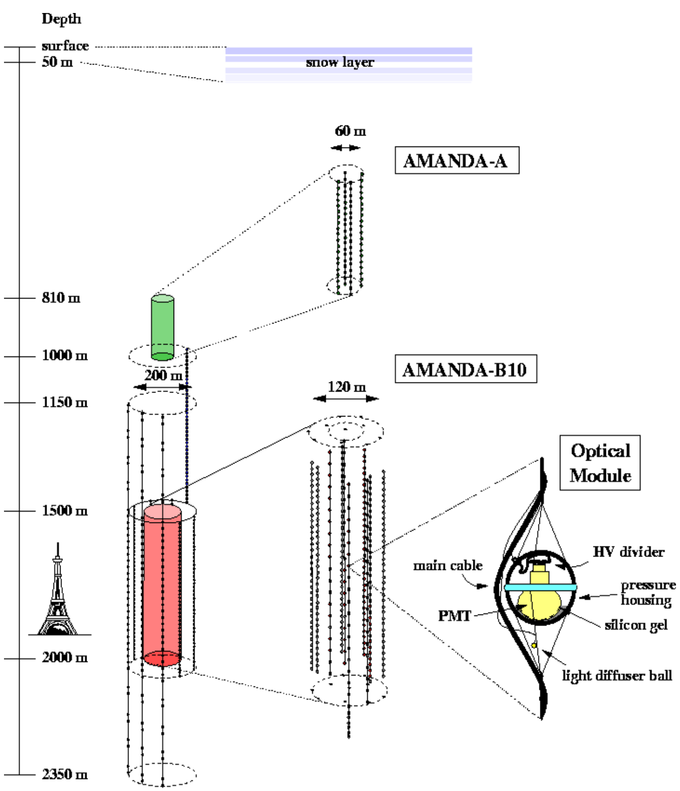
For a supernova 10 kiloparsecs away, expect ~100 neutrino interactions per kiloton

Need **QUIET** location (underground, away from cosmic radiation)



There are various kinds of neutrino detectors...

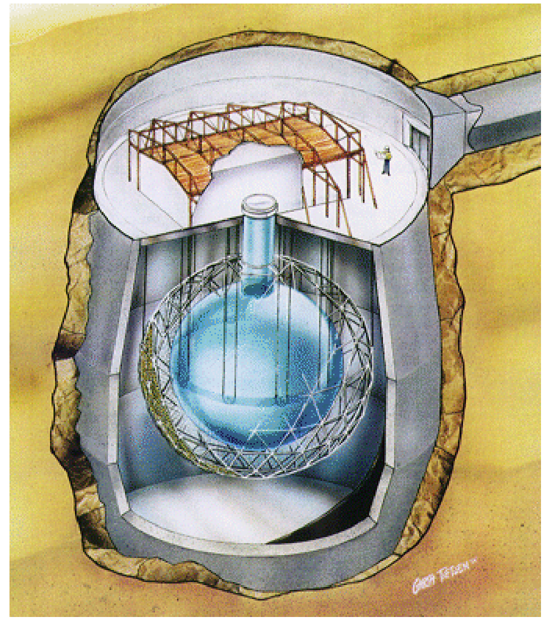


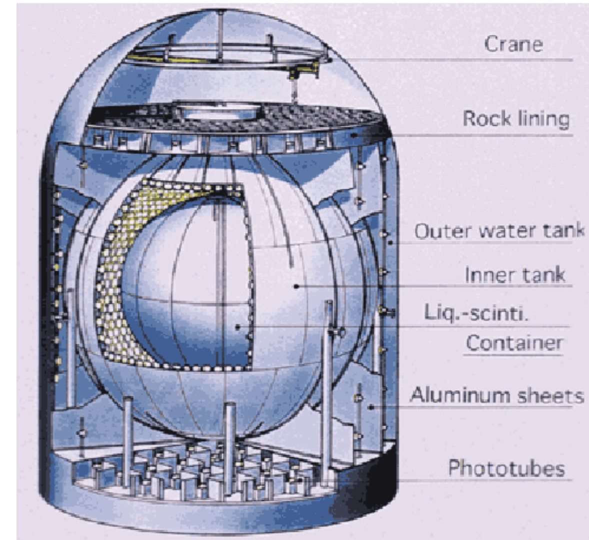


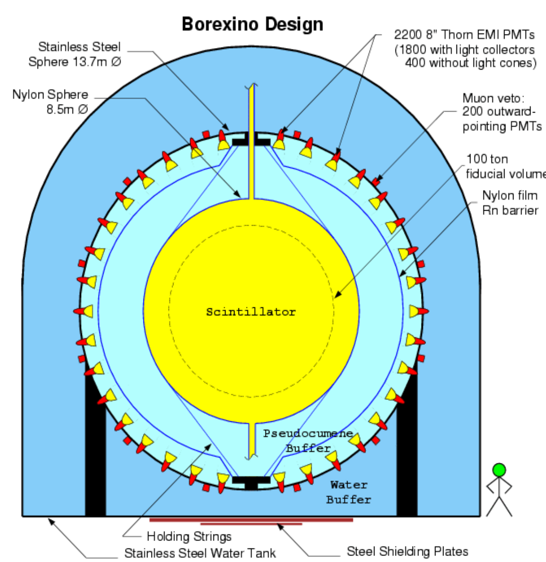
AMANDA as of 2000
Eiffel Tower as comparison
(true scaling)

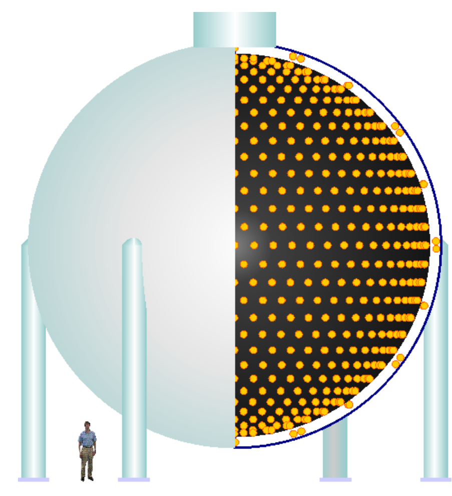
zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)

zoomed in on one
optical module (OM)



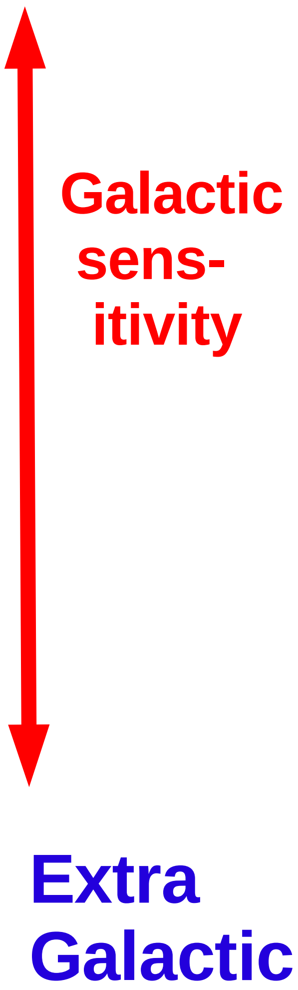






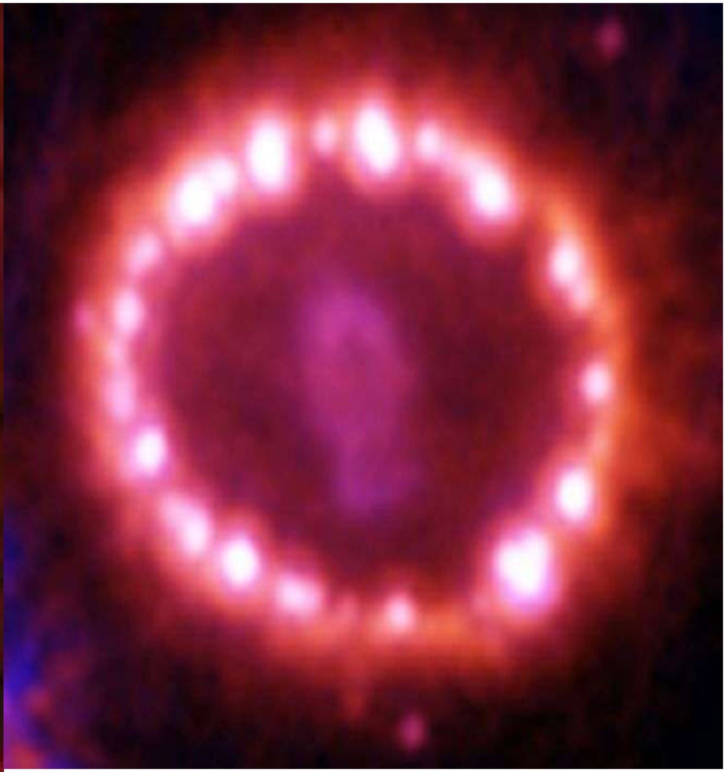
Summary of Supernova Neutrino Detectors

Detector	Type	Mass (kton)	Location	No. of events at 8.5 kpc	Status
Super-K	Water Cherenkov	32	Japan	7000	Running again for SN by Nov 2002
SNO	Heavy water	1.4 (D_2O), 1 (H_2O)	Canada	300 450	running
LVD	Scintillator	1	Italy	200	running
KamLAND	Scintillator	1	Japan	300	running
Borexino	Scintillator	0.3	Italy	100	2003
Baksan	Scintillator	0.33	Russia	50	running
Mini-BooNE	Scintillator	0.7	USA	200	running
AMANDA	Long string	M_{eff}~0.4/PMT	South Pole	N/A	running
Icarus	Liquid argon	2.4	Italy	200	2002
OMNIS	Pb	2-3	USA?	>1000	proposed
LANNDD	Liquid argon	70	USA?	6000	proposed
UNO	Water Cherenkov	600	USA?	>100,000	proposed
Hyper-K	Water Cherenkov	1000	Japan	>100,000	proposed 2009

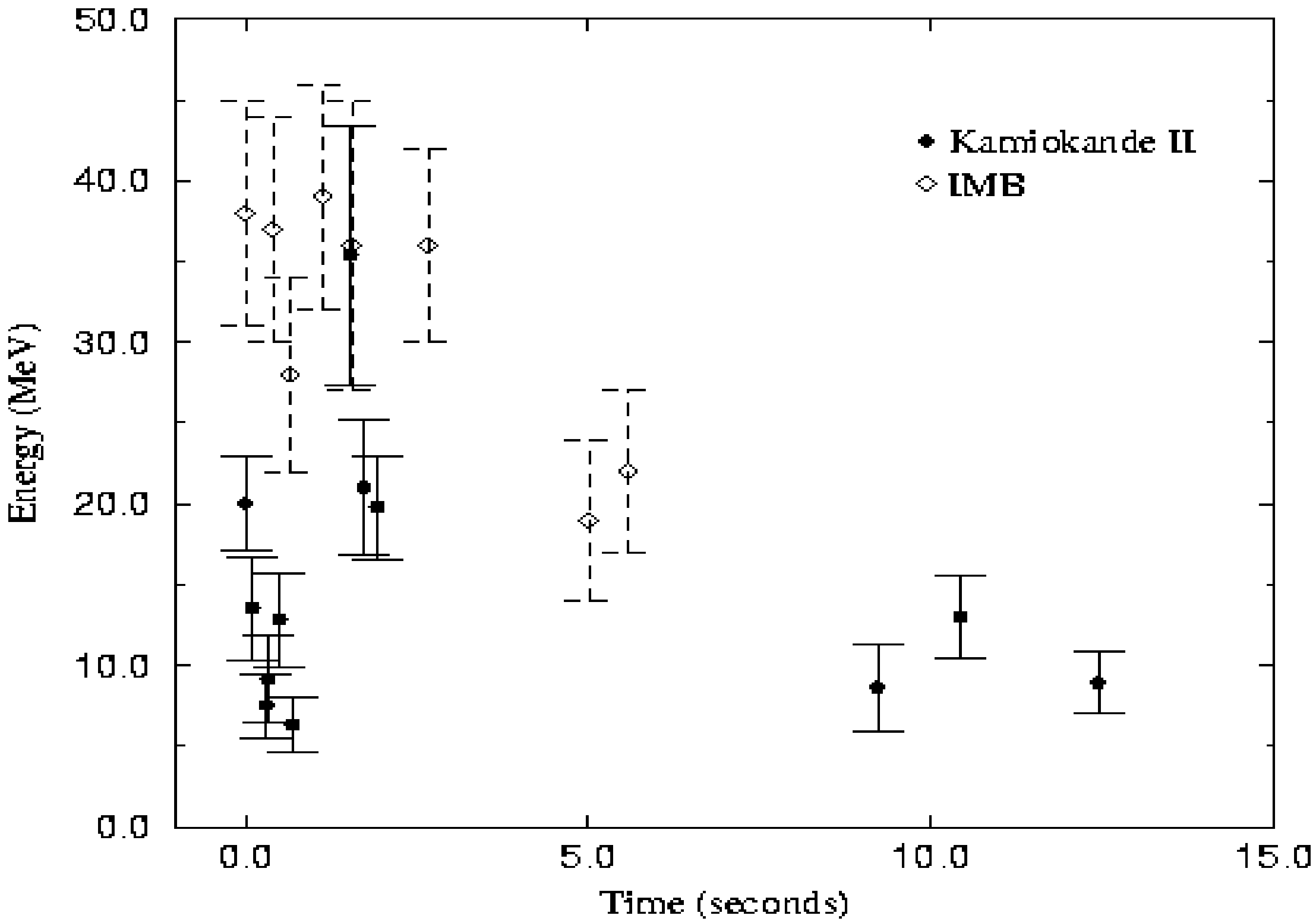


SN1987A

Type II in the Large Magellanic Cloud (~55 kpc)



A total of 19 neutrinos detected in two underground detectors!



Confirmed baseline model...
but still many questions

What Can We Learn from Supernova Neutrinos?

NEUTRINO PHYSICS

Mass and other properties

CORE COLLAPSE PHYSICS

Explosion mechanism, neutron star, black hole formation

ASTRONOMY FROM EARLY ALERT

An **EARLY ALERT** for astronomers

The neutrinos emerge *promptly* after core collapse, but the photons can take hours or even days, dependent on the nature of the stellar envelope

$\Rightarrow$ ~hours of warning

(1987A: -2.5 hours, but no alert)

Observations of light curve turn-on very rare for extragalactic SNae

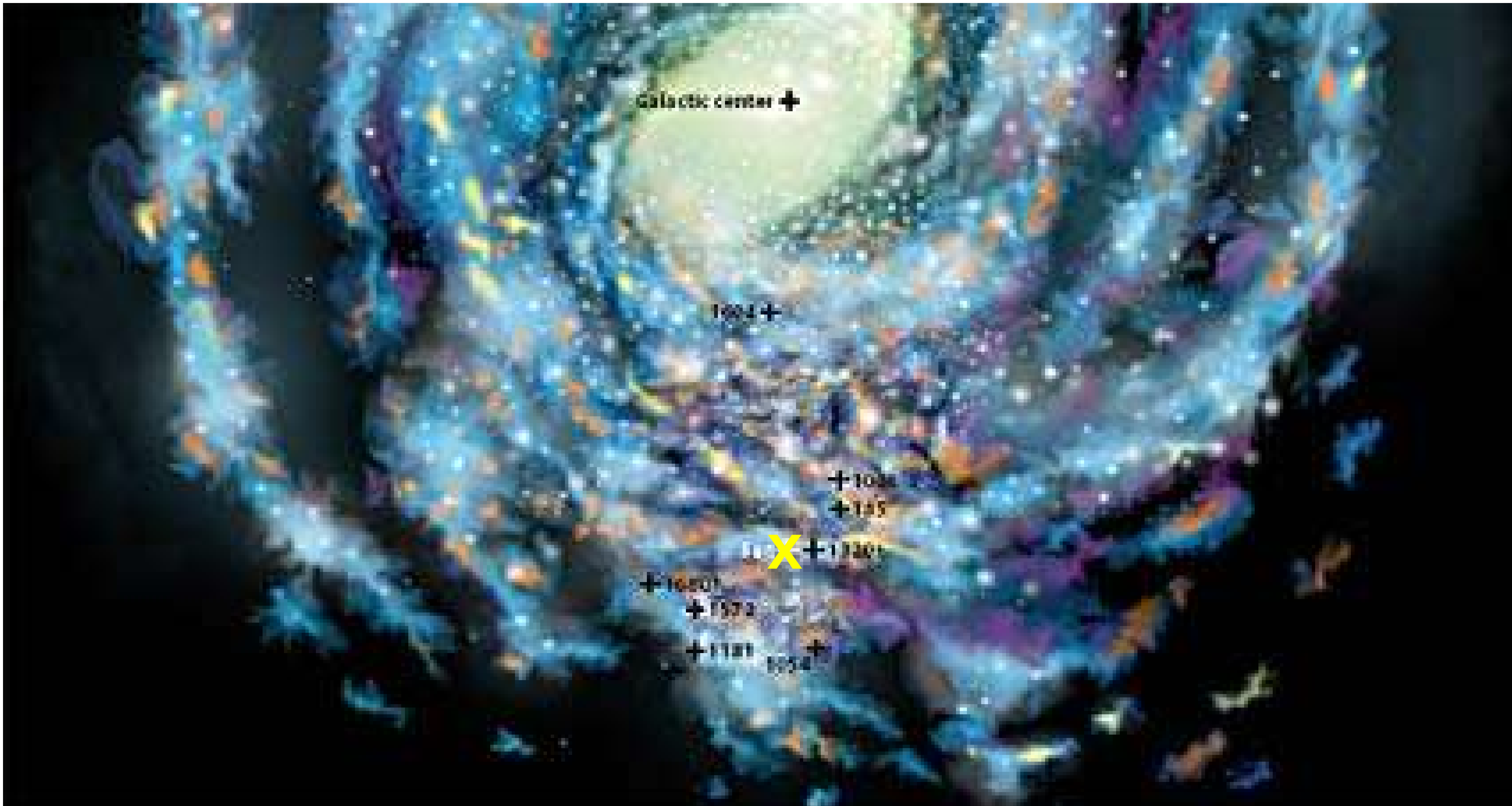
Especially valuable for learning about the progenitor, its environment

Plus: possible unknown early effects!

Possibly 1/6 will stand out obviously...

Historical Supernovae:

(Sky&Telescope)



Note: fireworks *may* be intrinsically dim (unknown)

Any information saved, in any channel, may be valuable

- all photon wavelengths
- neutrinos (low and high energy)
- gravitational waves
- ...

Implementation of the Early Alert

SNEWS: SuperNova Early Warning System

Computer(s) receive "blind" alert messages from neutrino experiments; automated alert if *coincidence* between 2 or more

(individual experiments are too noisy!)

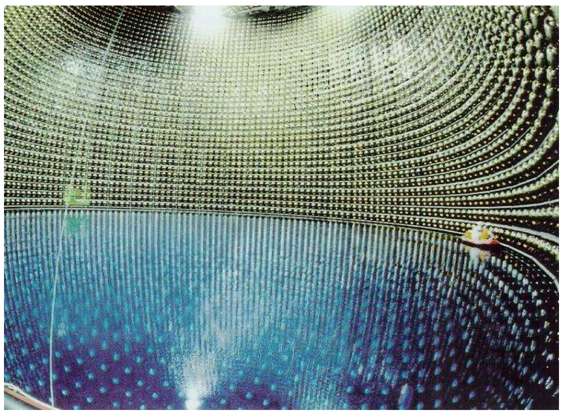
Goals:

- **alert for astronomers**
- **optimize global sensitivity to physics from SN ν burst**
  - **downtime coordination**
  - **timing verification**

Implementation of the Early Alert

SNEWS: SuperNova Early Warning System

Super-K (Japan)



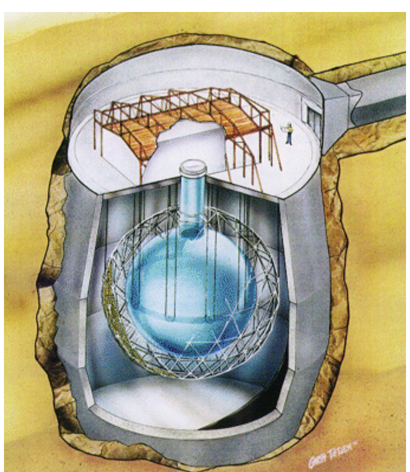
Coincidence Server

10 second coincidence by UT time stamp

Server at Brookhaven National Lab

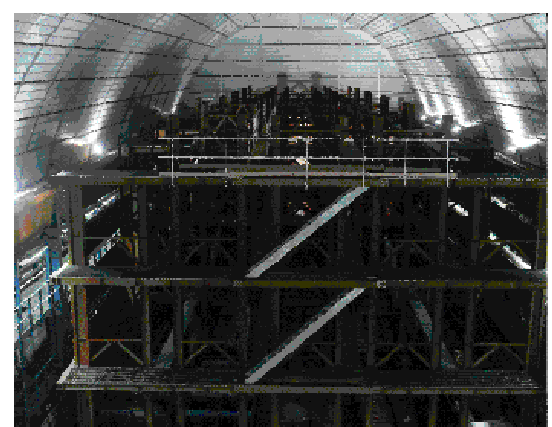
alert to astronomers

SNO (Canada)



experiment
UT time
significance

LVD (Italy)



What do Astronomers Want from an Early Warning?

"The 3 P's "

PROMPT — < hours, if possible (racing the shock)

POINTING — where to look?

POSITIVE — no false alarms!

Neutrino experimenters must address these as well as possible...

How well can we address the 3 P's?

"PROMPT"

Generally, ~10 minutes or
less is easily achievable for an automated alert;
limited by individual experiments

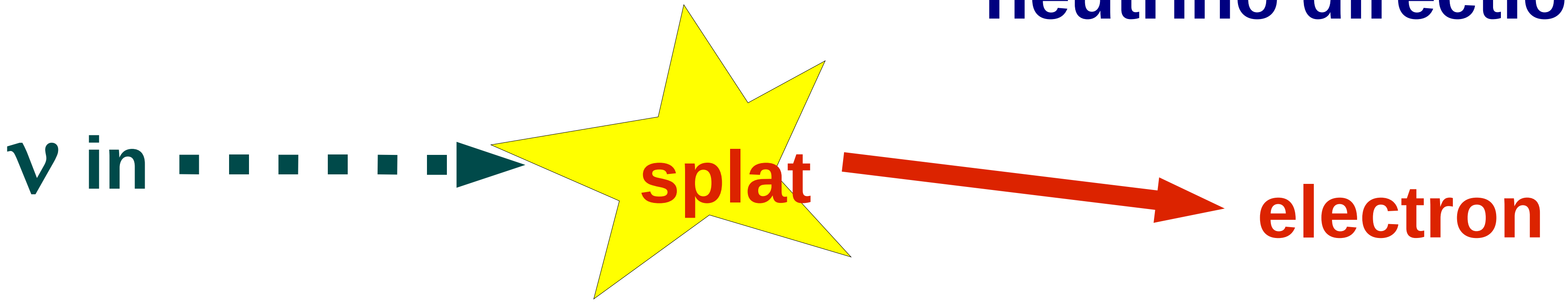
Currently,
Super-K, SNO and LVD can achieve this

Alerts should be as
automated as possible, to save time

POINTING

This is harder, but some pointing with neutrinos is possible

Few percent of interactions: electron gets kicked in roughly neutrino direction



⇒ Super-K can point back to the SN within ~4º, SNO ~15º for SN at 10 kpc

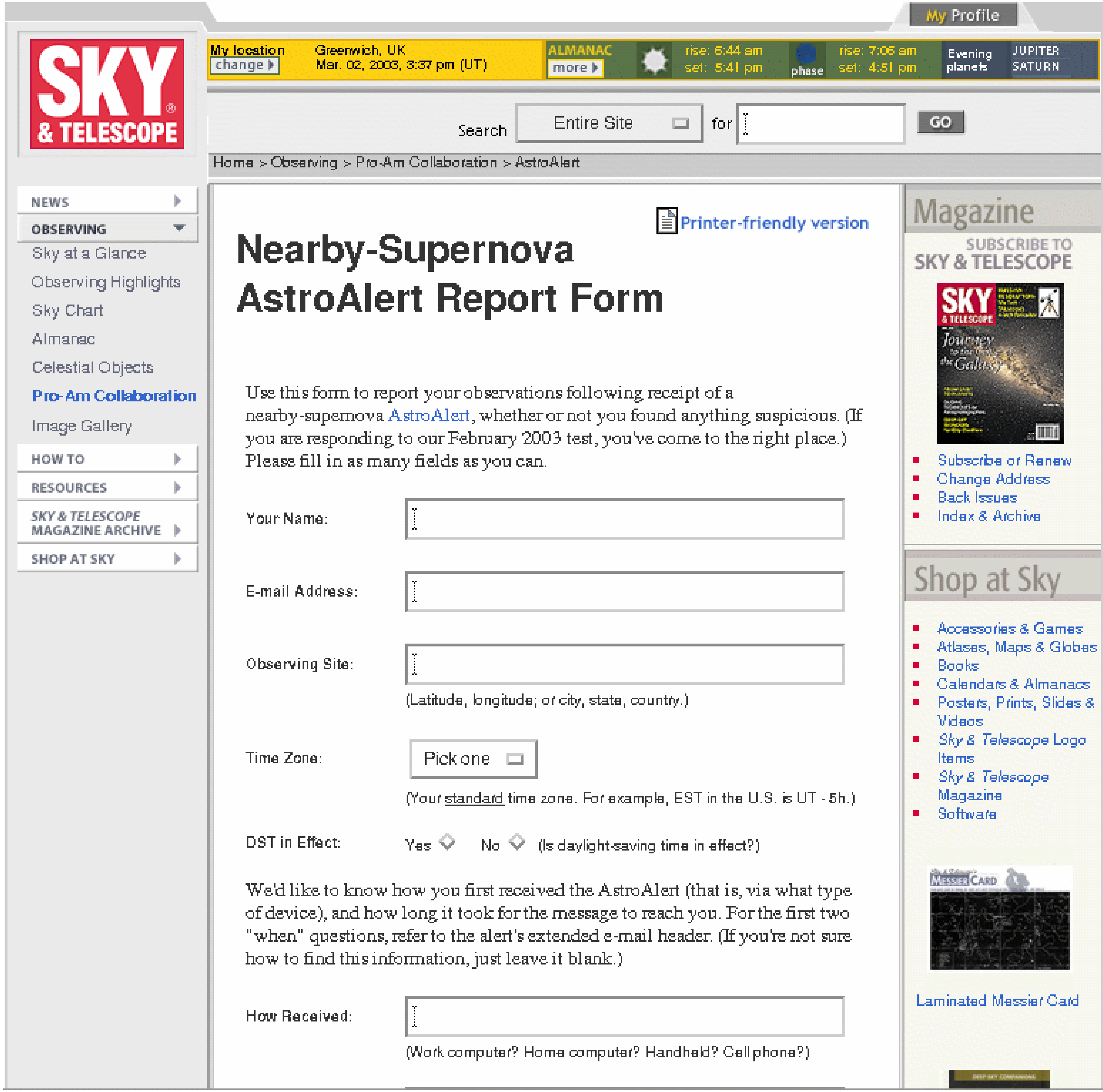
"POSITIVE" **No false alarms!**

Require individual experiment rates such that "accidental" coincidence between 2 or more is

less than 1 per century

GOLD: automated to community
SILVER: to experimenters only

The Sky & Telescope AstroAlert mailing list



My Profile

My location change | Greenwich, UK Mar. 02, 2003, 3:37 pm (UT) | ALMANAC more | rise: 6:44 am set: 5:41 pm | phase | rise: 7:06 am set: 4:51 pm | Evening planets | JUPITER SATURN

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Nearby-Supernova AstroAlert Report Form

Use this form to report your observations following receipt of a nearby-supernova AstroAlert, whether or not you found anything suspicious. (If you are responding to our February 2003 test, you've come to the right place.) Please fill in as many fields as you can.

Your Name:

E-mail Address:

Observing Site:
(Latitude, longitude; or city, state, country.)

Time Zone: Pick one
(Your standard time zone. For example, EST in the U.S. is UT - 5h.)

DST in Effect: Yes No (Is daylight-saving time in effect?)

We'd like to know how you first received the AstroAlert (that is, via what type of device), and how long it took for the message to reach you. For the first two "when" questions, refer to the alert's extended e-mail header. (If you're not sure how to find this information, just leave it blank.)

How Received:
(Work computer? Home computer? Handheld? Cell phone?)

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Laminated Messier Card

SUMMARY

A Galactic supernova will be a terrific opportunity for physics & astrophysics...

The neutrinos beat the photons by ~hours; neutrino detectors around the world will provide an *early warning*

Part II: Making an MC Tuning Sample

Detector simulations include many parameters
that can be modified in software to change
the simulation output

Some are well known...

e.g. size of PMTs, water density

Some might not be...

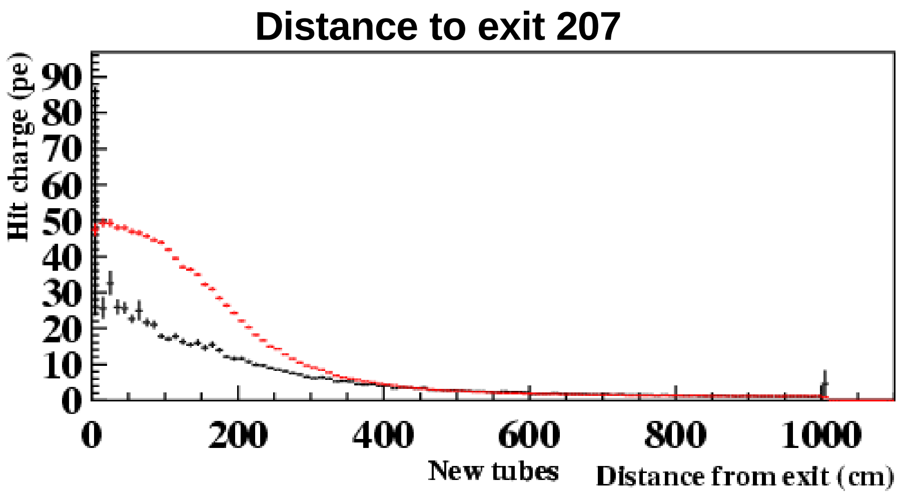
e.g. water transparency, reflectivity
of detector materials

⇒ 'tune' them by selecting values
to try to make data and MC match

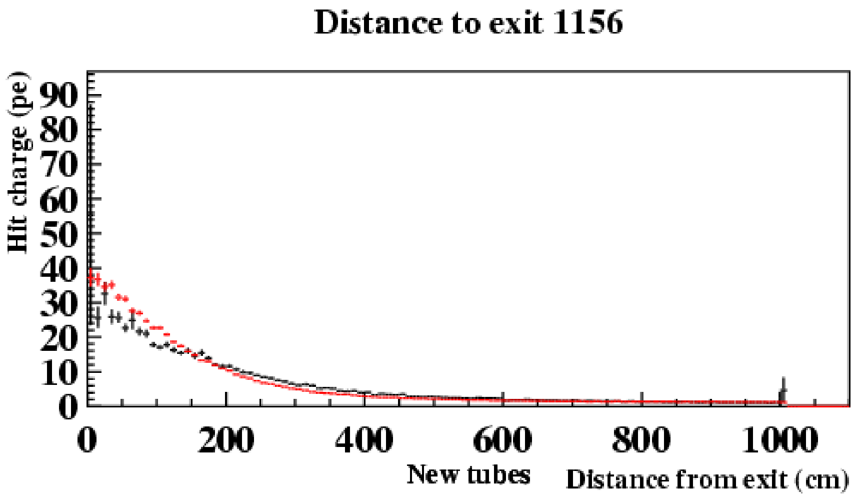
Typically, take a sample of matched data and MC events, make relevant plots for both, and tweak MC parameters until they match as well as possible:

Data: black; MC: red

Old tune



New tune



better agreement after parameters tweaked

For this last tutorial/exercise, you will make a matched sample that could be used for MC tuning

- Take a file of stopping muons (data)
- Fit (reconstruct) them using the `muboy` fitter
- Create a kinematics file using fit direction and entry point
- Simulate these events with `skdetsim`
- Make distributions of nqisk (no. of ID hits) for data and MC, and plot them superimposed