

# The SuperNova Early Warning System

SNEWS 2.0 and Software for Studying Supernova Neutrinos

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*College*  
**LONDON**



SN1987A—before and after

(Image credit: Anglo-Australian Observatory)



# Supernova

- ♦ Massive star explodes, leaving a neutron star or black hole
- ♦ ~99% of energy emitted as neutrinos
- ♦ Unique insights into astro-, particle and nuclear physics under extreme conditions
- ♦ Problem: just 1–3 SN/century in our Milky Way!



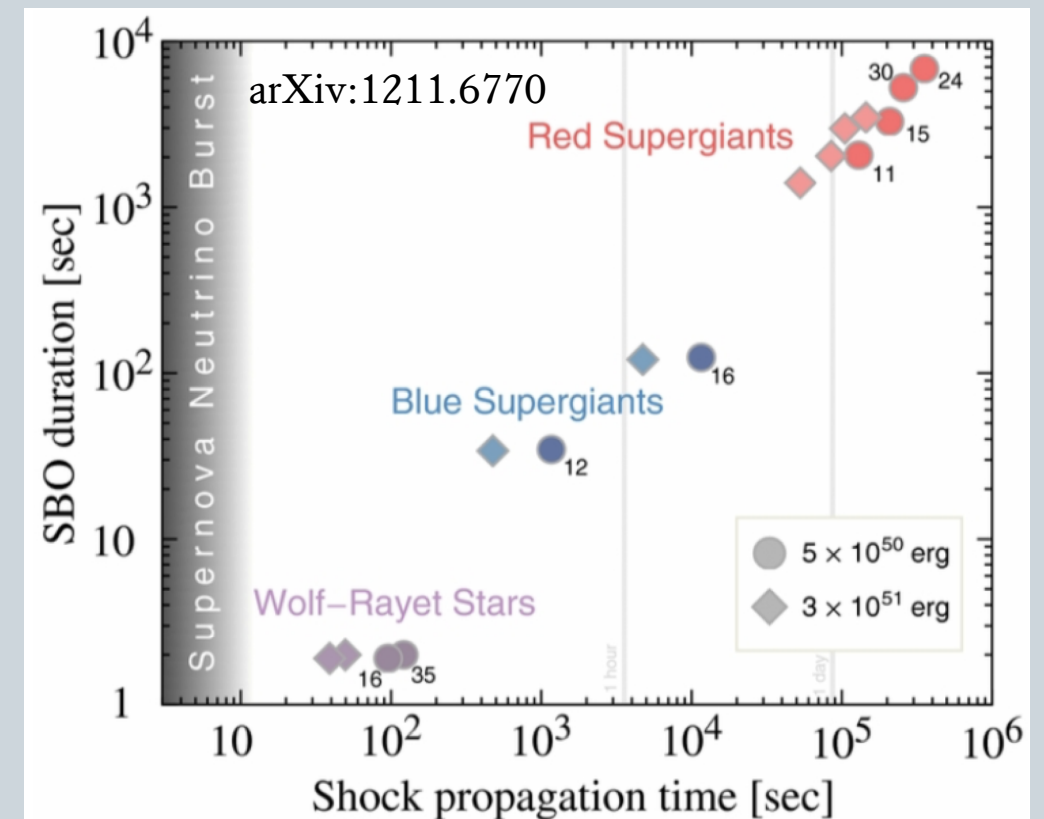
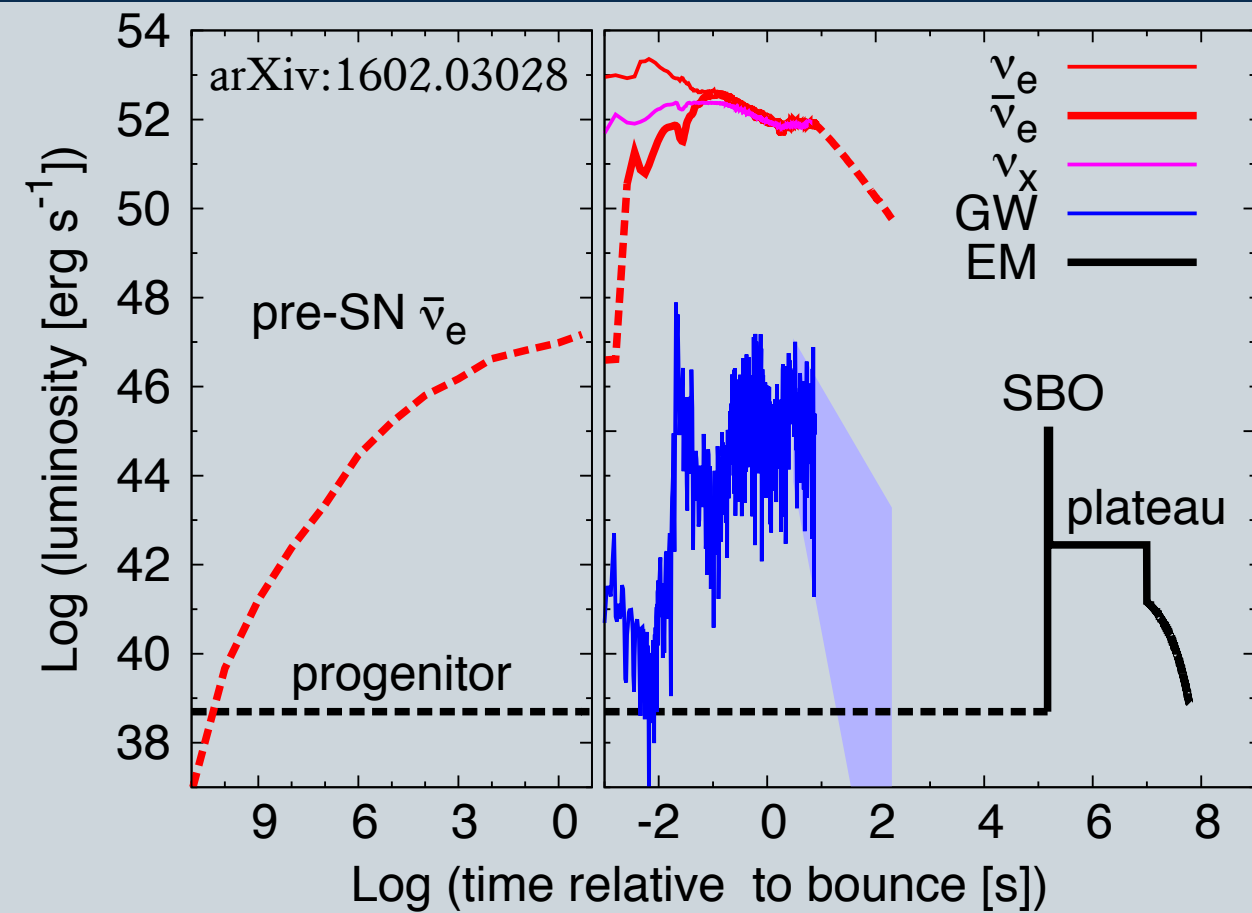
SN1994D in galaxy NGC 4526

NASA/ESA, Hubble Key Project Team, High-Z SN Search Team  
<http://www.spacetelescope.org/images/opo9919i/>

Note: In this talk, “supernova” is short for “core-collapse supernova”. Type Ia SNe have a different physical mechanism and produce fewer neutrinos, so I’ll ignore them. (Apart from SN1994D, because this photo is so pretty.)

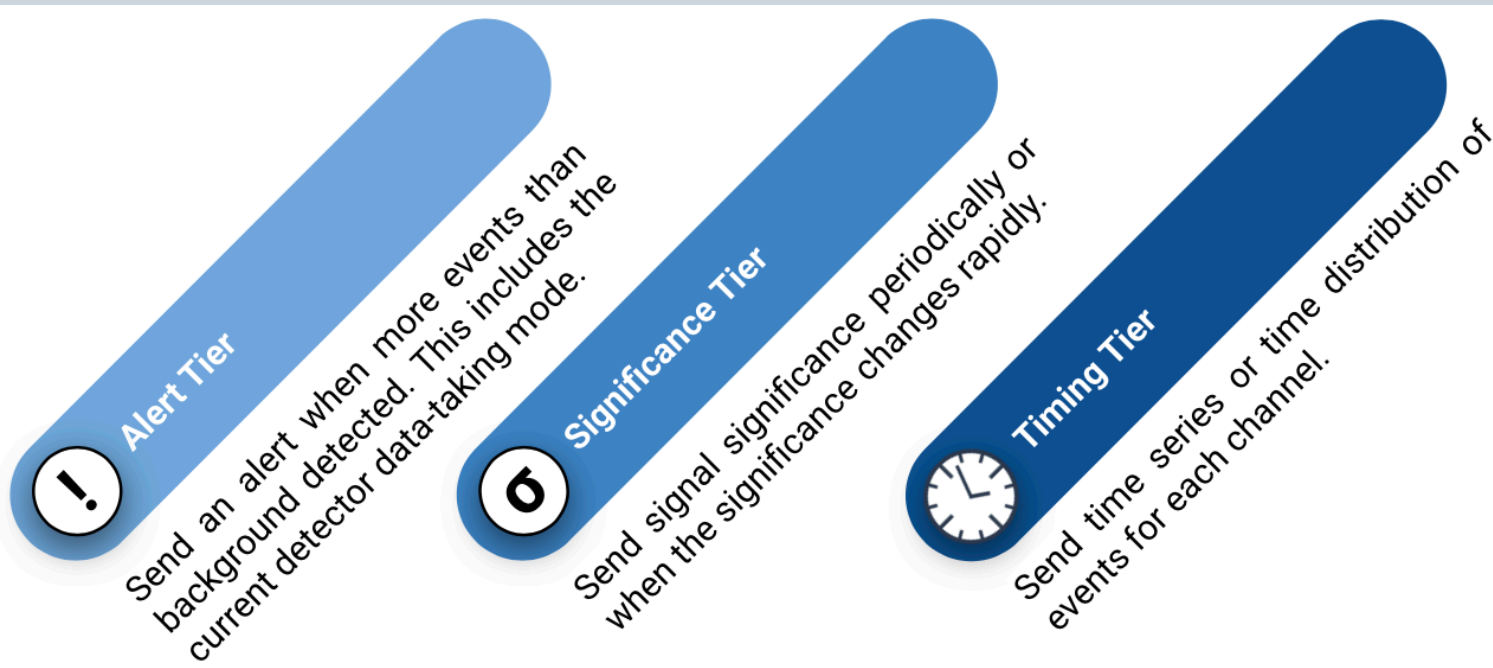
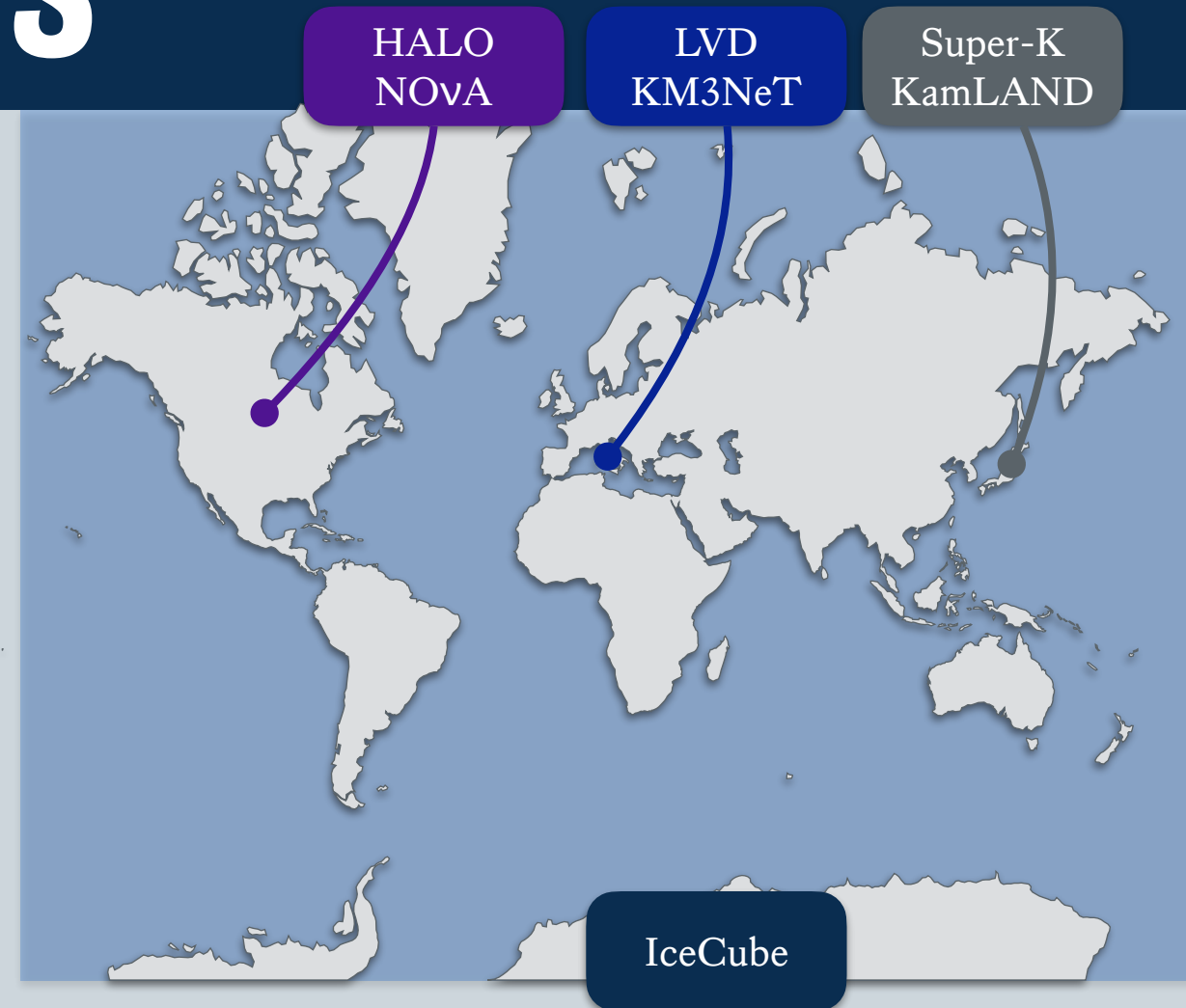
# Supernova

- Once-in-a-lifetime event  
→ Extract as much multi-messenger information as possible!
- Neutrinos emitted minutes to hours before light
- Can build a **SuperNova Early Warning System** with neutrino detectors



# SNEWS

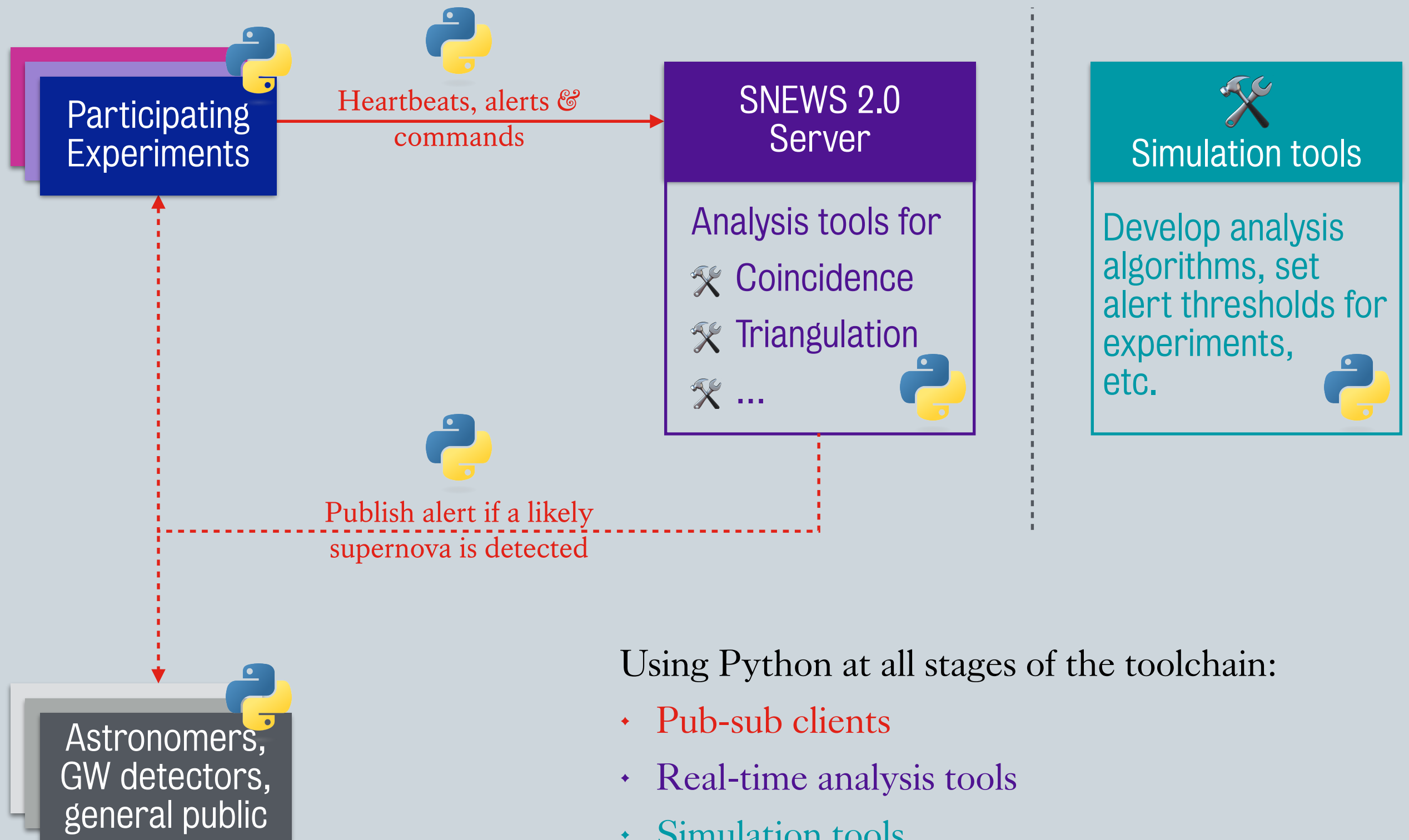
- ♦ Started >20 years ago, running in automated mode since 2005
- ♦ Today: 7 participating detectors →
- ♦ Started to re-imagine SNEWS for the age of multi-messenger astronomy ([arXiv:2011.00035](https://arxiv.org/abs/2011.00035) / [DOI:10.1088/1367-2630/abde33](https://doi.org/10.1088/1367-2630/abde33))



## New features:

- ♦ Reduced alert threshold
- ♦ Pointing information
- ♦ Follow-up strategy
- ♦ ... *and much more!*

# SNEWS 2.0 Software Overview



Using Python at all stages of the toolchain:

- ♦ **Pub-sub clients**
- ♦ **Real-time analysis tools**
- ♦ **Simulation tools**
- ♦ (Internal tools of many participants & subscribers)

- ♦ Scalable **C**yber**i**nfrastructure for **M**ulti-**M**essenger **A**strophysics
  - ♦ NSF-funded project used by IceCube, LIGO, ...
  - ♦ Develops HOPSKOTCH: “a scalable, high-throughput low-latency platform for handling real-time data streams for MMA applications”
- ♦ SNEWS & SCiMMA started close collaboration in 2020
  - ♦ SNEWS: Don't need to implement & maintain basics like identity/access management, pub-sub infrastructure, ...
  - ♦ SCiMMA: Real-world test of early prototype, rapid user feedback
- ♦ Paper: “Collaborative Experience between Scientific Software Projects using Agile Scrum Development” ([arXiv:2101.07779](https://arxiv.org/abs/2101.07779), [DOI:10.1002/spe.3120](https://doi.org/10.1002/spe.3120))



# SNEWS Publishing Tools

- ♦ Developing SNEWS Publishing Tools on top of HOPSKOTCH
- ♦ **Publish** or subscribe from notebook or CLI
- ♦ `schema_version` and `meta` included in every message schema

```
: from snews_pt.snews_pub import SNEWTiersPublisher
from datetime import datetime
test_time = datetime.utcnow().strftime("%y/%m/%d %H:%M:%S:%f")

message = SNEWTiersPublisher(detector_name='XENONnT',
                             machine_time=test_time,
                             neutrino_time=test_time,
                             p_val=0.0007,
                             p_values=[0.001, 0.02, 0.005],
                             t_bin_width=0.5,
                             firedrill_mode=False)

message.send_to_snews()
```

```
-----
Sending message to CoincidenceTier on kafka://kafka.scimma.org/snews.experiments-test
_id              :19_CoincidenceTier_22/08/03 02:05:43:869112
detector_name    :XENONnT
machine_time     :22/08/03 02:05:43:869112
neutrino_time    :22/08/03 02:05:43:869112
p_val            :0.0007
meta             :{}
schema_version   :1.1.0
sent_time        :22/08/03 02:05:43:878058
-----
Sending message to SigTier on kafka://kafka.scimma.org/snews.experiments-test
_id              :19_SigTier_22/08/03 02:05:43:869112
detector_name    :XENONnT
machine_time     :22/08/03 02:05:43:869112
```

```
jost@Macintosh ~/D/A/S/S/snews_pt (main)> snews_pt publish my_alert.json
```

```
schema_version   :1.1.0
sent_time        :22/08/03 02:05:43:878058
```

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```
In [*]: from snews_pt.snews_sub import Subscriber
Subscriber().subscribe()

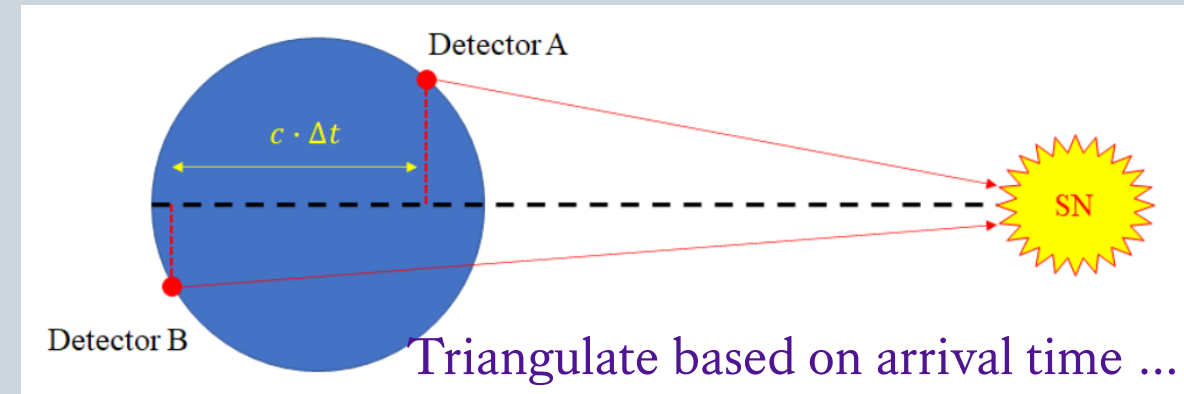
You are subscribing to ALERT
Broker:kafka://kafka.scimma.org/snews.alert-firedrill
```

```
(snews) kara-unix@iap-nb-034:auxiliary$ ls custom*
custom_script.py
(snews) kara-unix@iap-nb-034:auxiliary$ snews_pt subscribe -p custom_script.py
Redirecting output to custom_script.py
You are subscribing to ALERT
Broker:kafka://kafka.scimma.org/snews.alert-firedrill
```

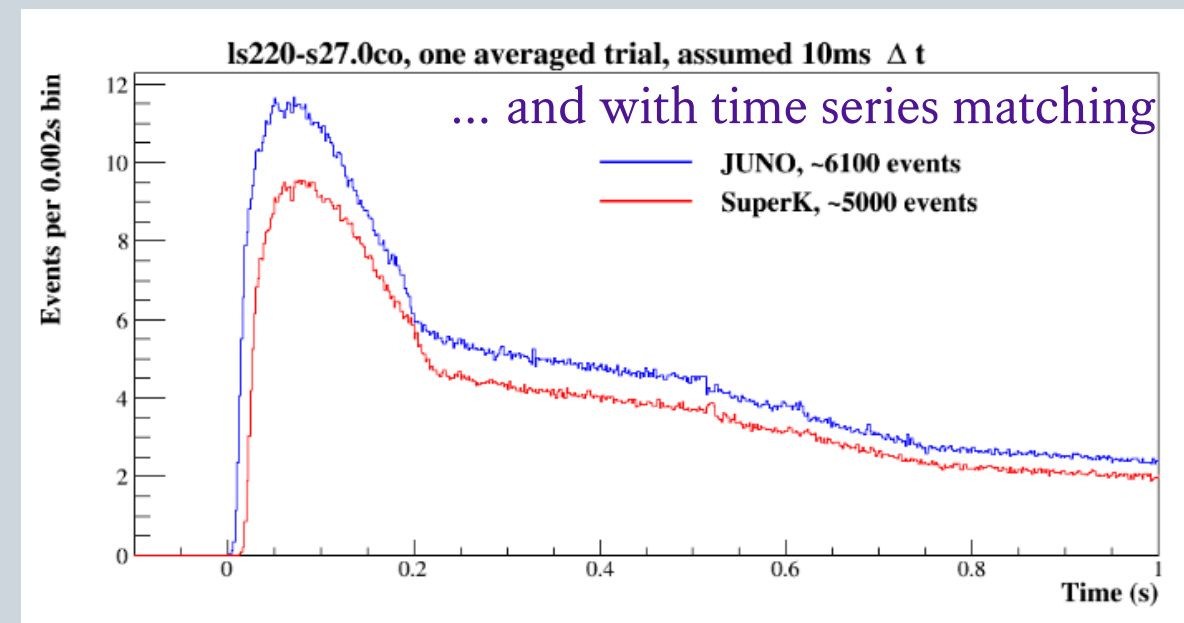


# Real-time Analysis Tools

- ♦ Publicly available [on GitHub](#)



- ♦ Coincidence System
- ♦ Heartbeat Handler
- ♦ SNEWPDAG



- ♦ Directed **A**cyclic **G**raph built from different plugins
- ♦ Estimate distance, **triangulate direction**, compare with progenitor distribution, ...

# Offline Simulation Tools: SNEWPY

SNEWPY offers ...

- ♦ ... a simple and unified interface to hundreds of supernova simulations.
- ♦ ... a large library of flavor transformations that relate neutrino fluxes produced in the supernova to those reaching a detector on Earth.
- ♦ ... and a Python interface to SNOwGLoBES which lets you estimate and plot event rates in many different neutrino detectors.

*Can use these  
in your code!*

# Usage of SNEWPY

- ♦ SNEWS-internally
- ♦ By other software:
  - ♦ sntools ([DOI:10.21105/joss.02877](https://doi.org/10.21105/joss.02877))
  - ♦ ASTERIA ([DOI:10.5281/zenodo.3926834](https://doi.org/10.5281/zenodo.3926834))
- ♦ In non-SNEWS papers:

*smooth transition from  
quick initial estimates  
to advanced analyses*

## Neutrino Echos following Black Hole Formation in Core-Collapse Supernovae

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<sup>2</sup>Department of Physics, Oxford University, Oxford, UK

[arXiv:2203.05141](https://arxiv.org/abs/2203.05141)

[arXiv:2109.13242](https://arxiv.org/abs/2109.13242)

## Detectability of hadron-quark phase transition in neutrino signals of failing core-collapse supernova

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(Dated: March 11, 2022)



# SNEWPY Demo

- ♦ SNEWPY → Demo in Jupyter notebook
- ♦ Try it on Binder: [https://mybinder.org/v2/gh/JostMigenda/PyHEP2022/main?labpath=snewpy\\_demo.ipynb](https://mybinder.org/v2/gh/JostMigenda/PyHEP2022/main?labpath=snewpy_demo.ipynb)