



SNEWS 2.0:

The Multi-Messenger Supernova Early Warning System

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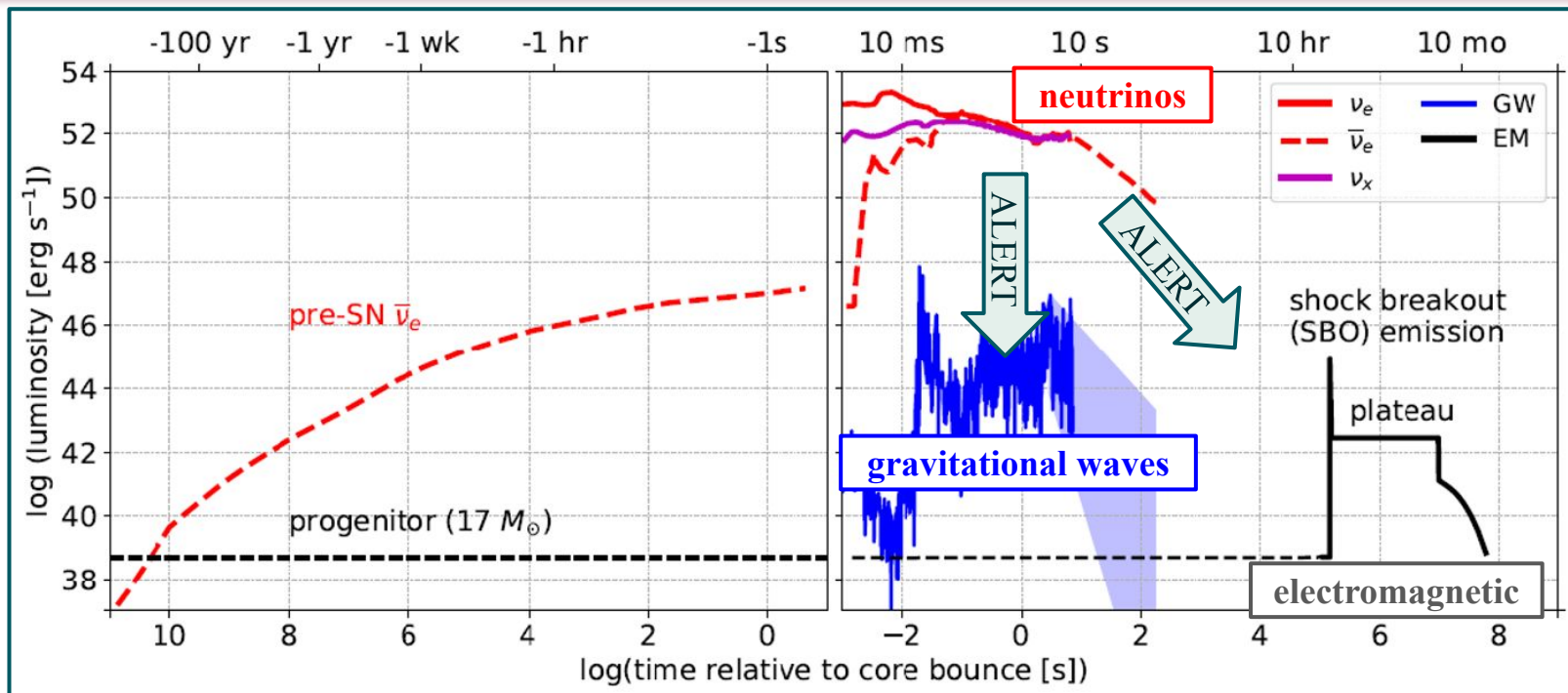


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Multi-Messenger Astrophysics



When the next galactic Core-Collapse Supernova happens, we will detect **neutrinos**, **gravitational waves**, and **Electromagnetic signals**.





SNEWS: SuperNova Early Warning System

- ★ Aims to provide the astronomy community with a prompt alert indicating the observance of neutrinos from a supernova event from within the Milky Way.

- ★ The expected rate of CCSN in the Milky Way is ~ 2 per century.

Rozwadowska et al: 2009.03438

We need to be prepared!





Goals of SNEWS



Prompt and automated alert system.



Provide an early warning for EM observers.



Timing window for GW signals.



Triangulation using multiple neutrino experiments.

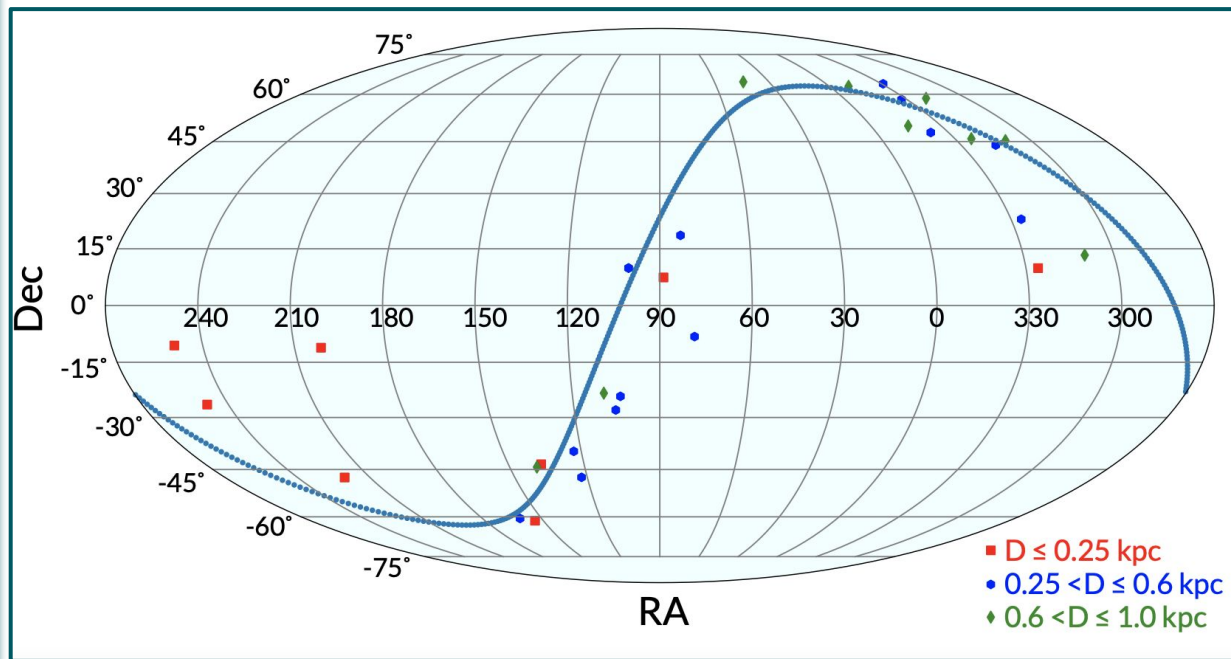




Pre-Supernova



$\bar{\nu}_e$ emission during Si burning is detectable hours to days before the explosion.

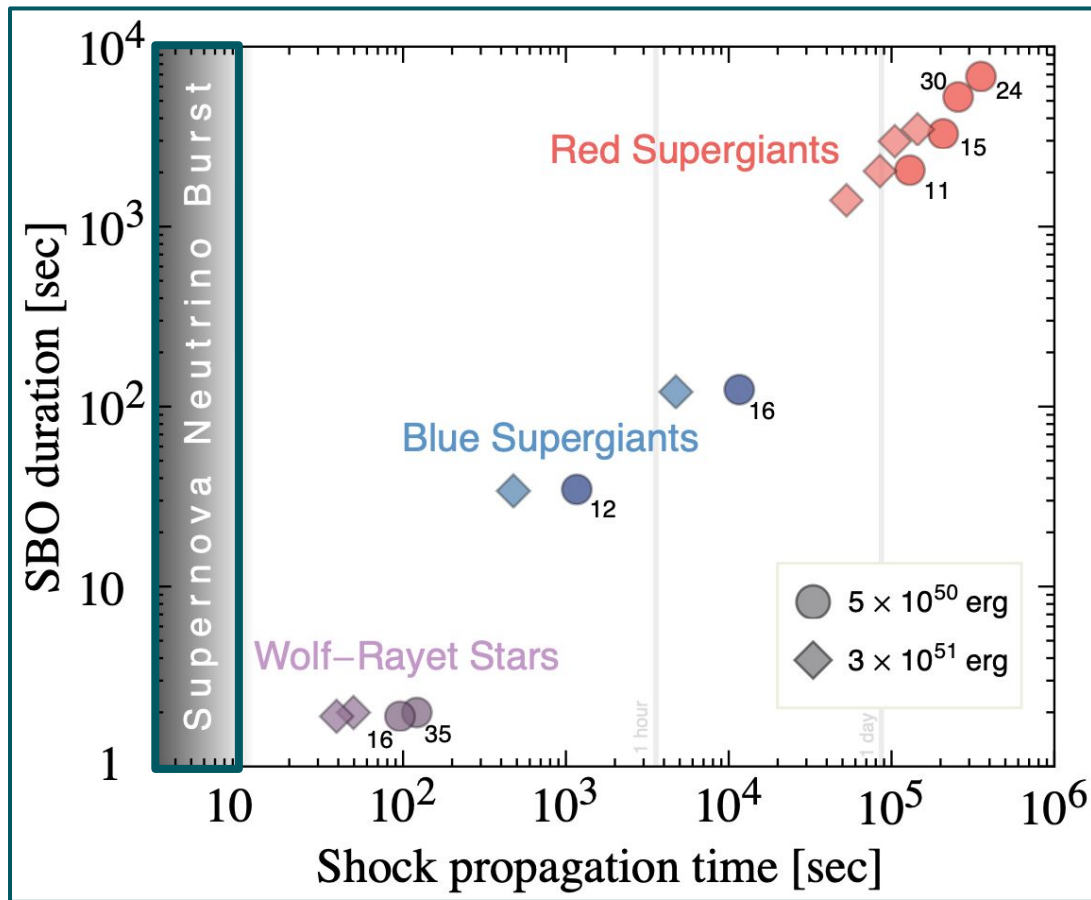




Prompt



Time between supernova neutrinos and EM signals ranges from a few minutes to a few days.



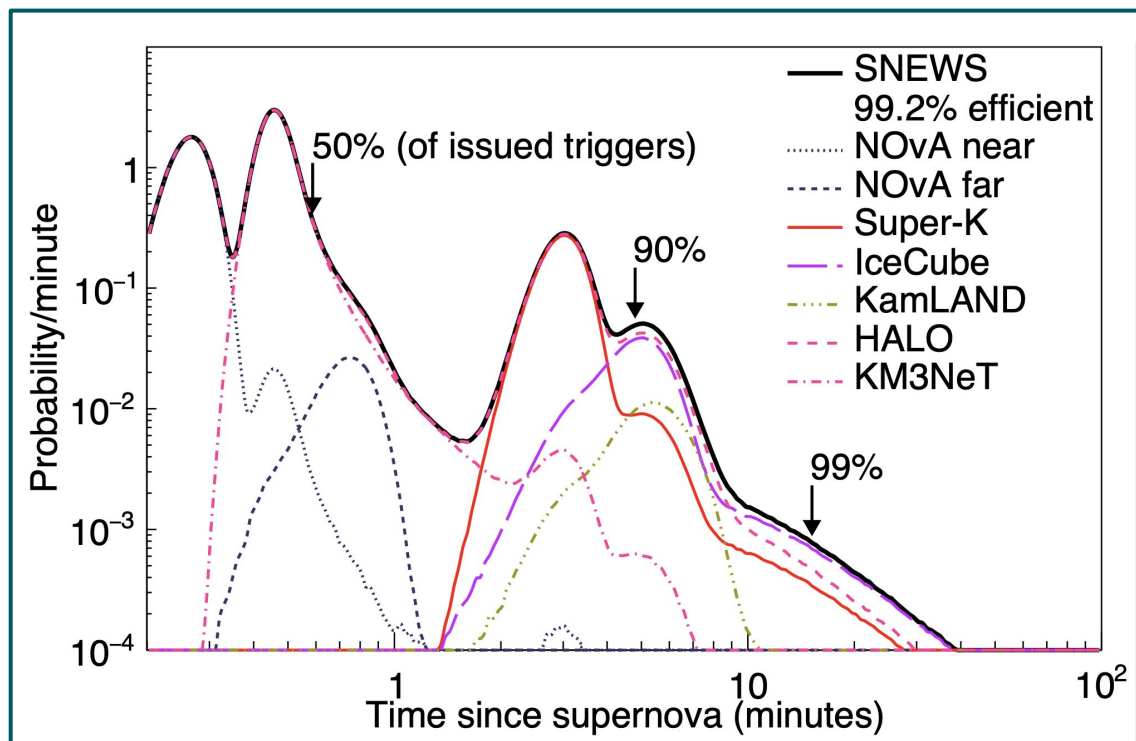


Prompt



Estimated latency from experiments is \mathcal{O} (minutes).

Expected latency for server is \mathcal{O} (seconds).

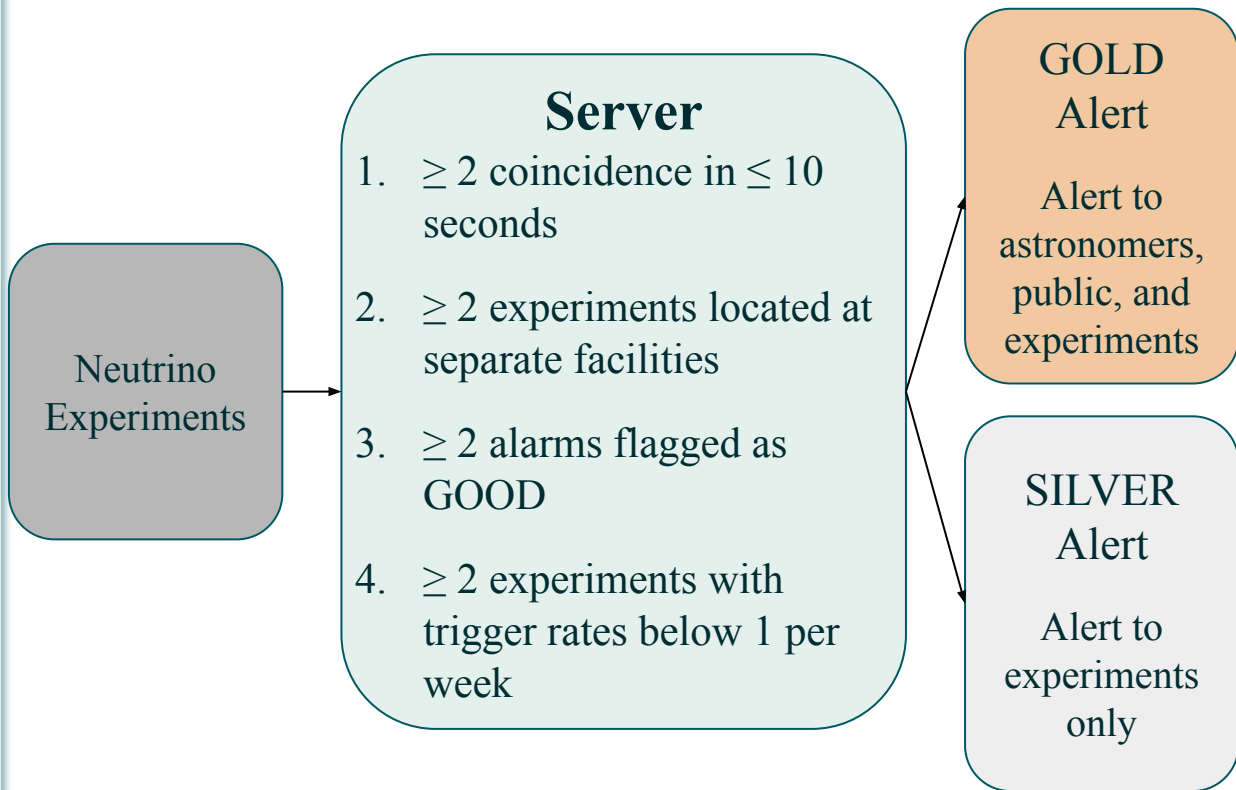




Positive



SNEWS 1.0 had a false alert rate of $< 1/\text{century}$.





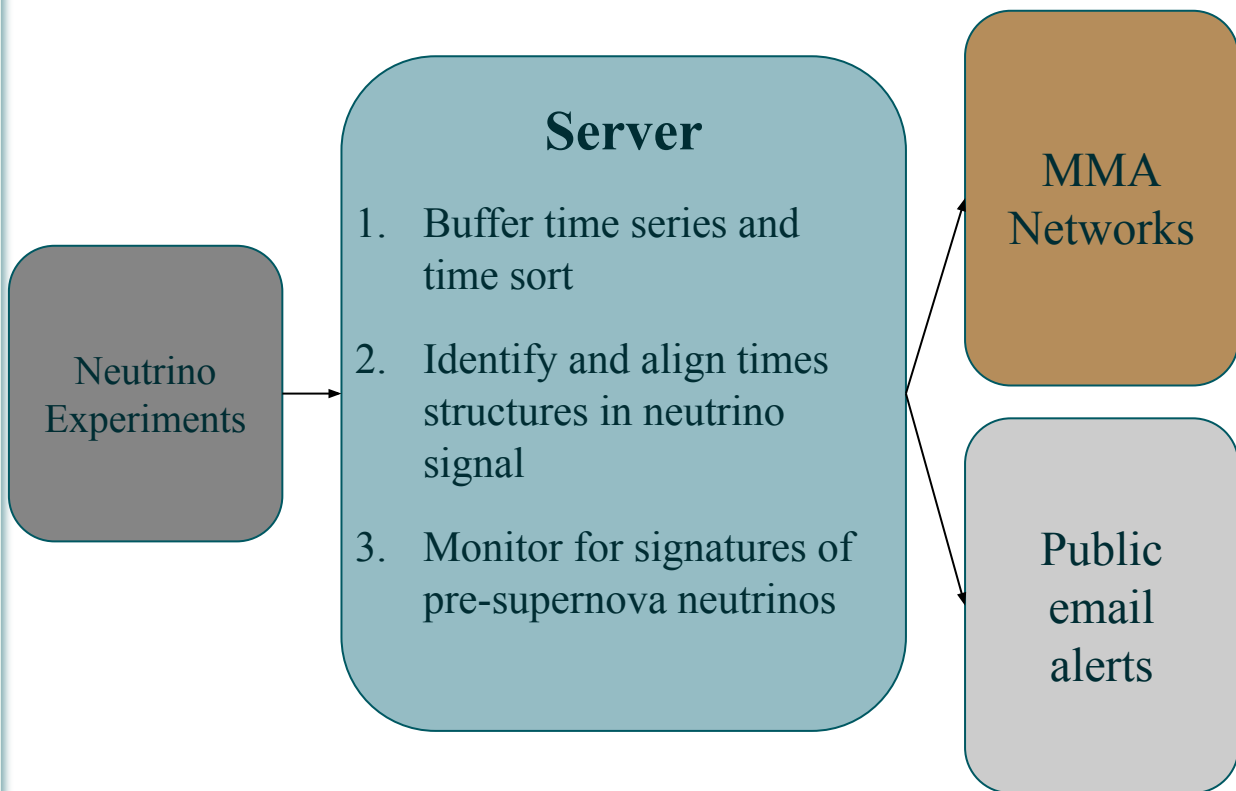
Positive



SNEWS 1.0 had a false alert rate of $< 1/\text{century}$.

SNEWS 2.0 will combine significance of supernova neutrinos to lower threshold for alerts.

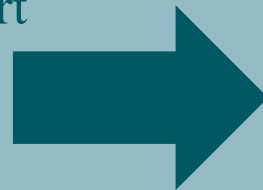
SNEWS 2.0





Server Essential Components

- 1) Function to read messages and decide if there is an alert
- 2) Message interfacing for clients
- 3) Server infrastructure to coordinate messaging





Alert Tier

Send an alert when more events than background detected. This includes the current detector data-taking mode.



Significance Tier

Send signal significance periodically or when the significance changes rapidly.



Timing Tier

Send time series or time distribution of events for each channel.



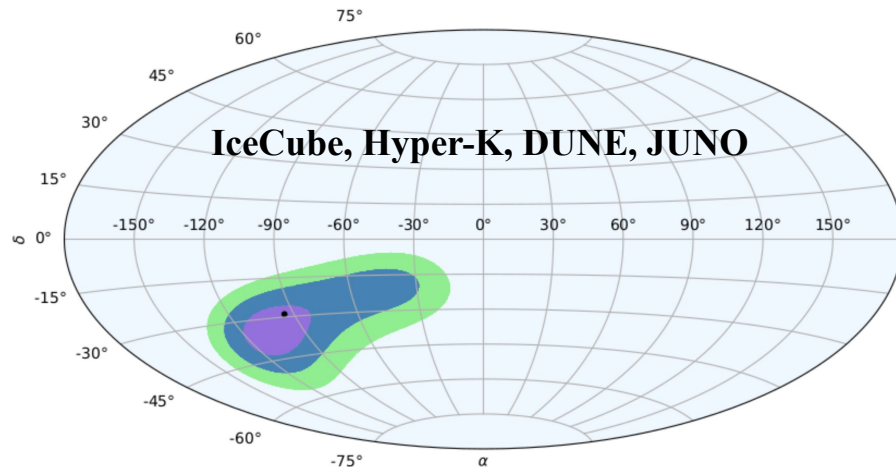
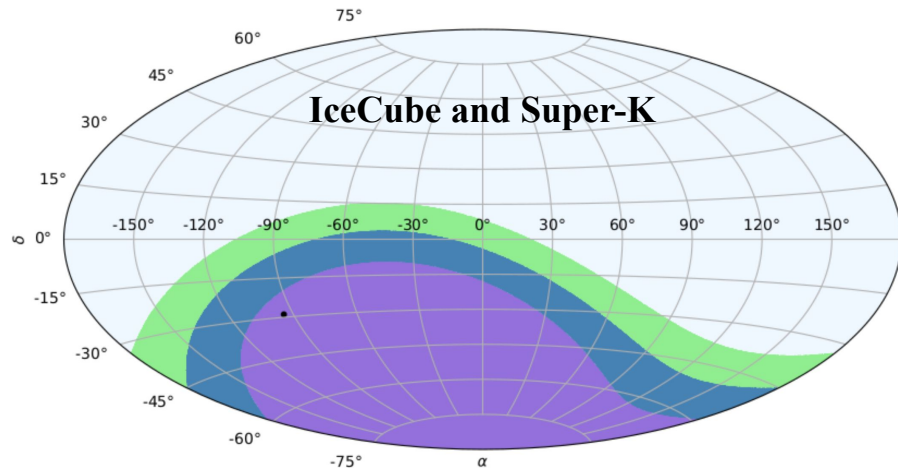


Pointing



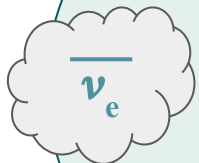
Look at arrival time difference of supernova neutrinos at different detectors.

$$\cos\theta_{ij} = \frac{c\Delta t_{ij}}{|\vec{d}_{ij}|}$$



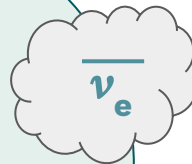


Water Cherenkov



Super-K
Hyper-K
IceCube
KM3NeT

Scintillator



Baksan
LVD
Borexino
KamLAND
JUNO
SNO+
NO ν A

Liquid Noble Dark Matter



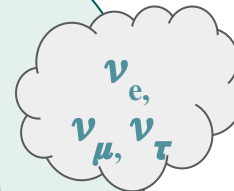
DarkSide
XENON
LZ
PandaX

ν & Low Background



DUNE
nEXO

Lead



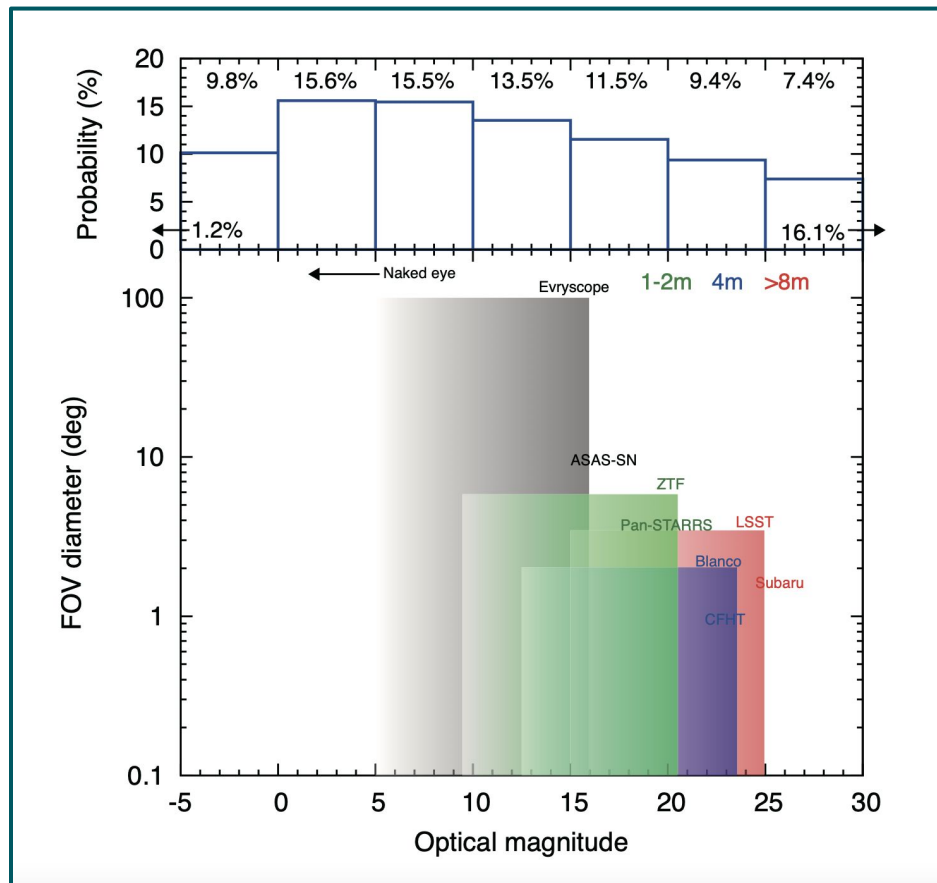
HALO
HALO-1kT



Follow-Up



Coordination with telescope networks, GW observatories and amateur astronomers will allow for effective follow-up organization.



Summary

- A core collapse supernova will produce a neutrino signal before the EM signal. → **Early Warning!**
- SNEWS 2.0 will have a broader network than before. More than 15 neutrino experiments including dark matter detectors.
- With SNEWS 2.0, we will:
 - produce more frequent alerts
 - conduct pre-supernova analyses
 - include pointing/triangulation
 - provide follow-up information