Features Detection following the SuperNova Early Warning System

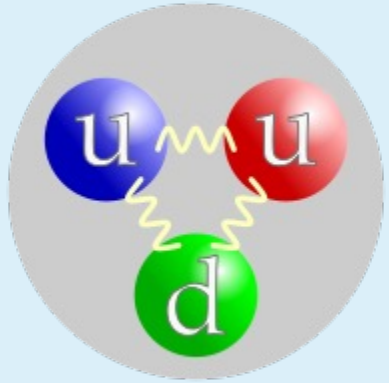
Tse Ho Yeung

Motivations

- “Prediction” of Core-collapse supernova with its feature

- Things we can observe with photons
- Secondary burst
- Blackhole forming

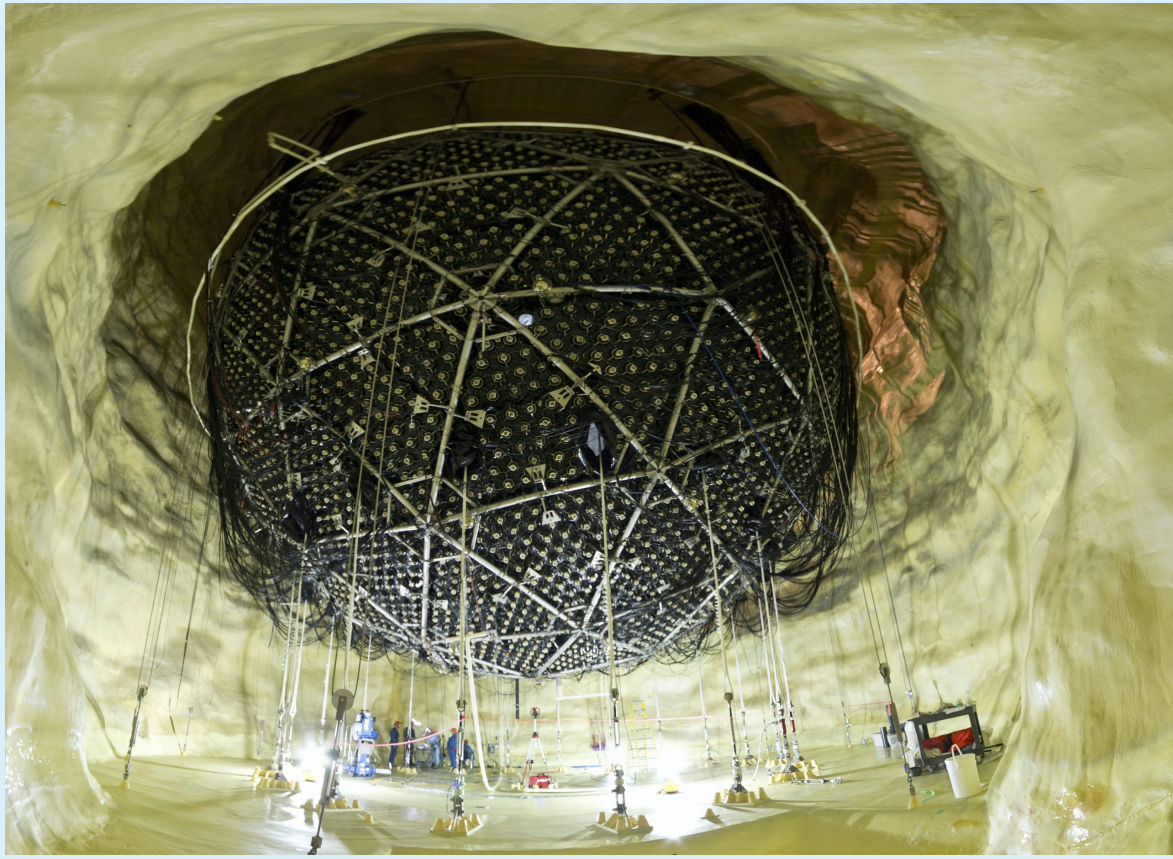
- A possible evidence for quark star
- Provide information to the observer communities



Background

- SuperNova Early Warning System
- Detection of supernova in our galaxy

- Neutrinos
- Core-collapse supernova
- Data from different detectors around the world
- Neutrinos reach a few hours before photons arrive

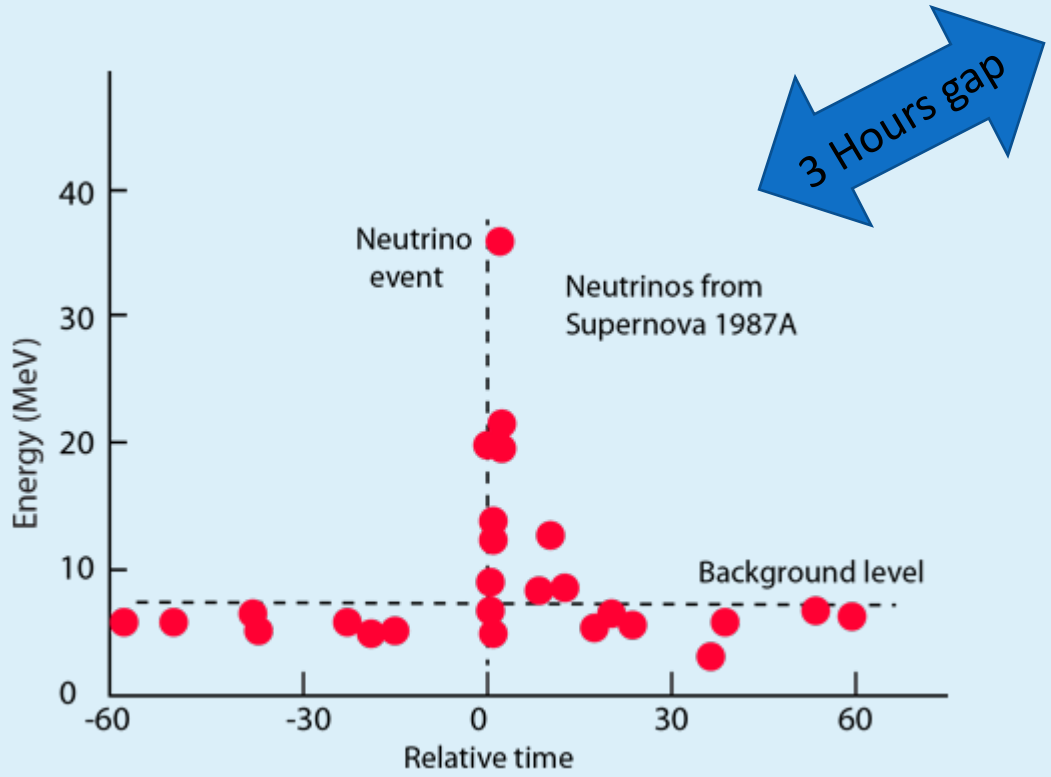


Neutrino detector in SNOLAB

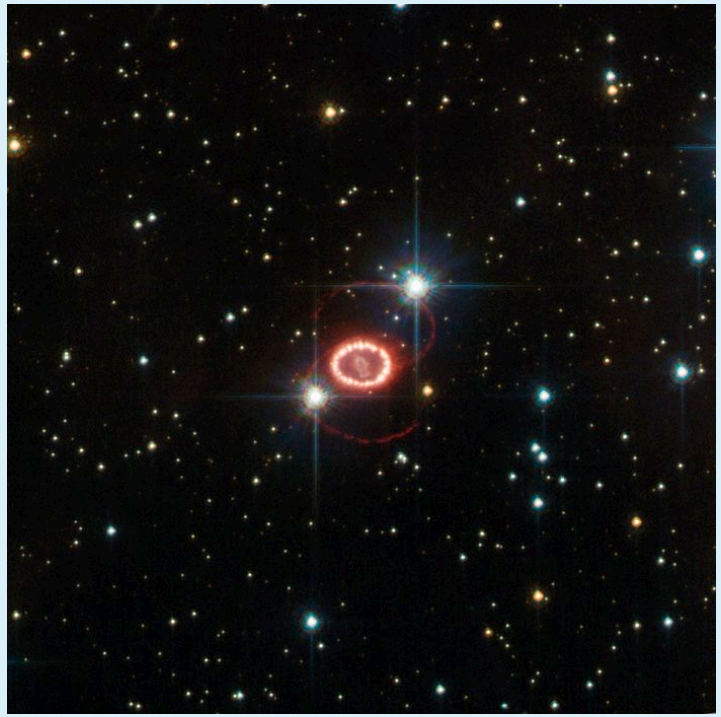
(picture from snolab.ca)

Core-collapse supernova and neutrinos

- Powerful – release a lot of energy
- 99% of the energy lost – via neutrinos
- Rare event
- Last detection:
  23 Feb, 1987



Halliday, Resnick & Walker: Fundamentals of Physics

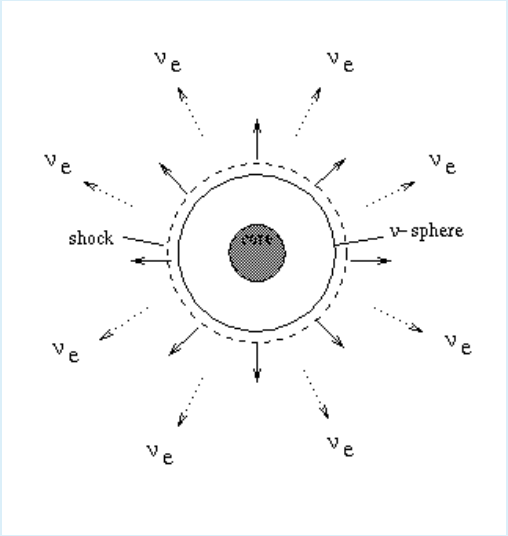


Remnant of SN1987A
ESA/Hubble & NASA

Preparation

Races against time

- Supernova
- A lot of information
- we missed a lot in 1987 - lack of advance detectors/observers
- SNEWS detecting neutrinos
- The very first detection
- A few hours before photons reach
- Prepare all algorithms in advance
- Gather as much information as we can for the follow-ups (e.g. skymap)



Possible features on supernova neutrinos

- Computational simulations in different models

- Oscillation

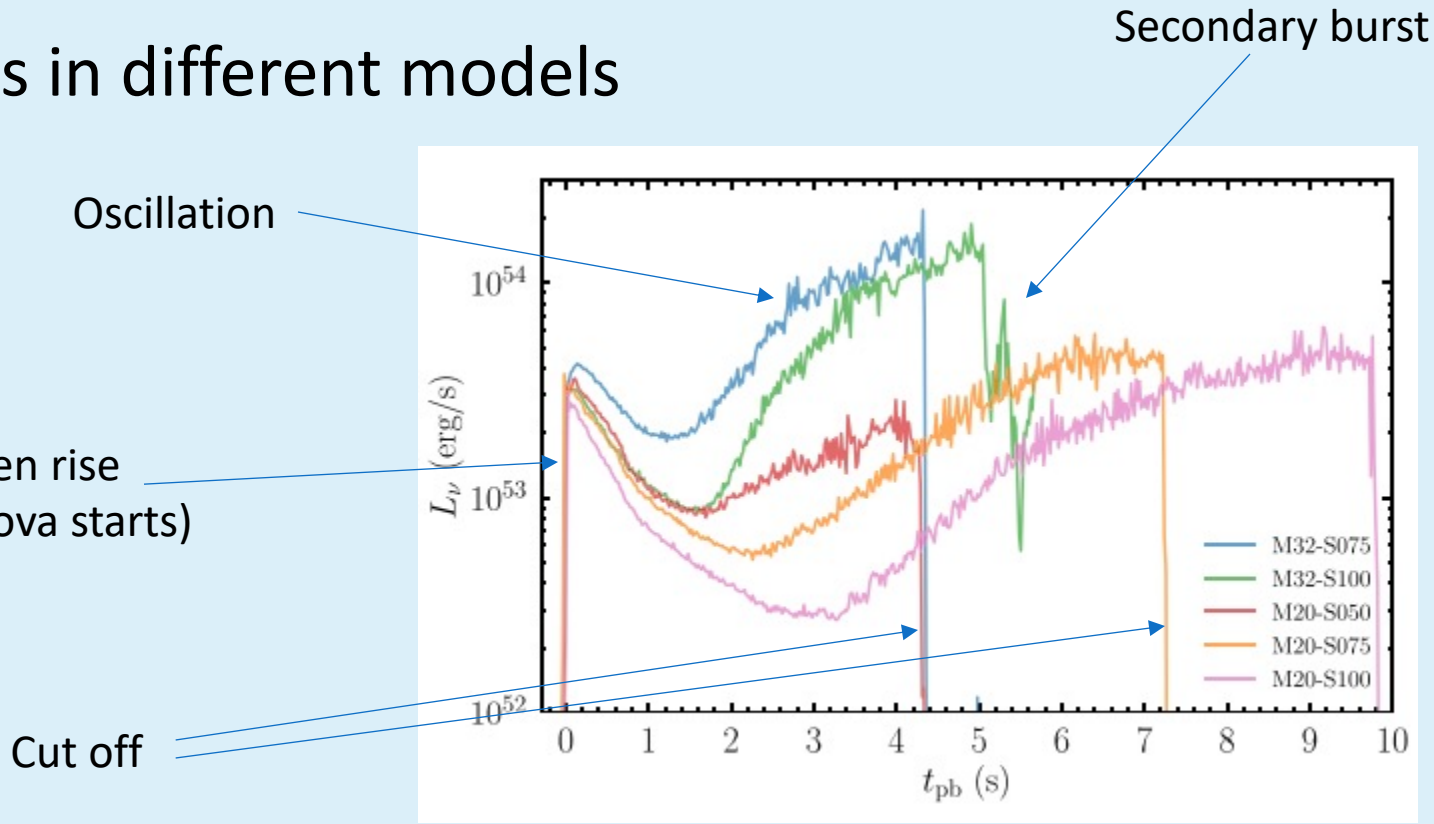
standing accretion shock instability

- Cut-off

Turned into a blackhole

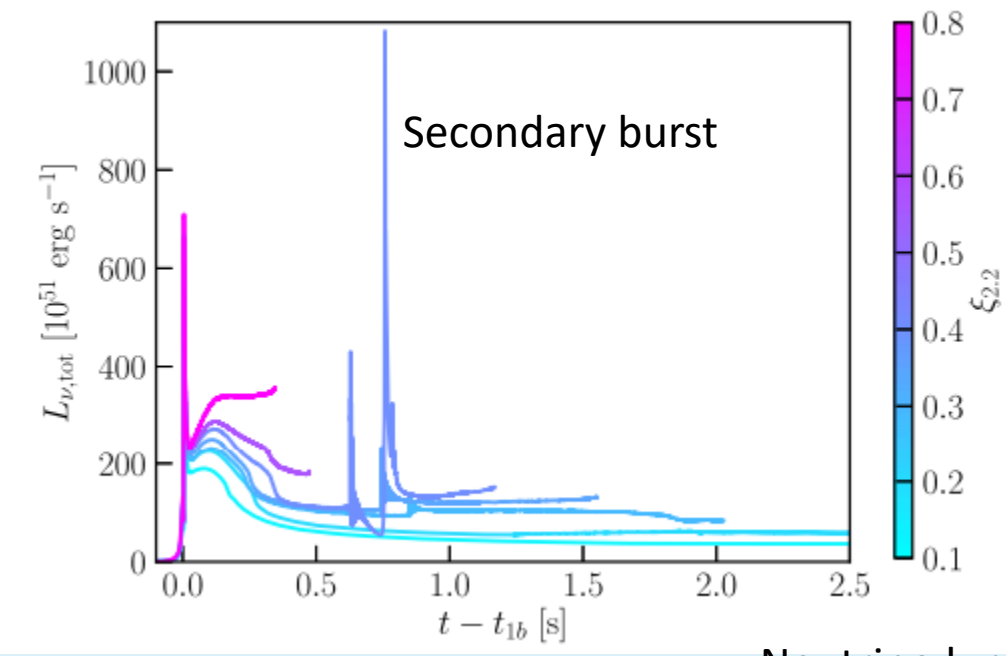
- Secondary burst

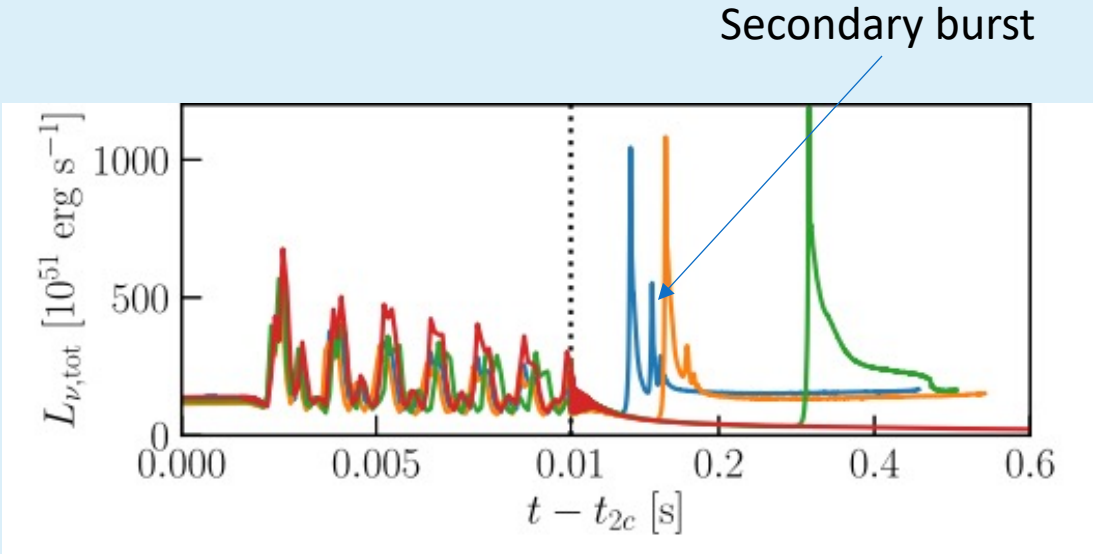
Phase passing through Quark star?



Fujibayashi et al., ApJ 919 (2021) 2, 80

Simulation from another supernova model



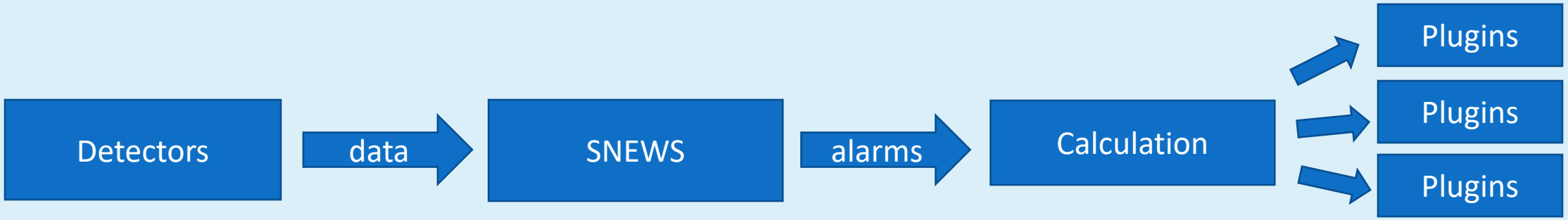


Neutrino luminosity vs time

Zha et al., ApJ 911 (2021) 2, 74

Calculation

- Algorithm in python (following the SNEWS)
- As a plugin in the follow-up calculating system (Snewpdag)



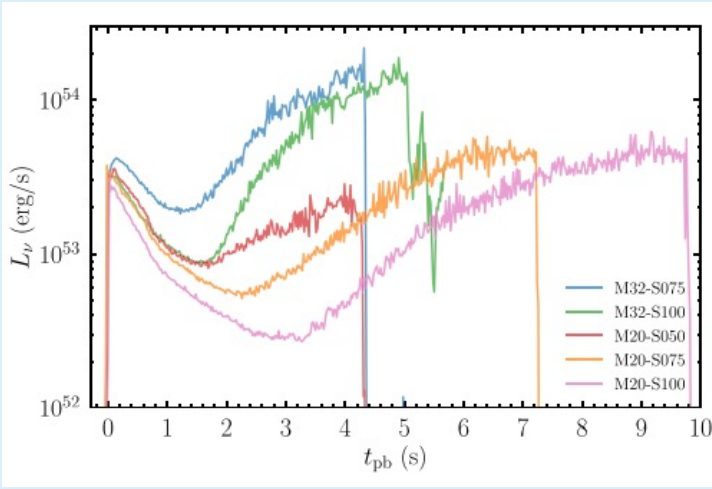
https://github.com/SNEWS2/snewpdag

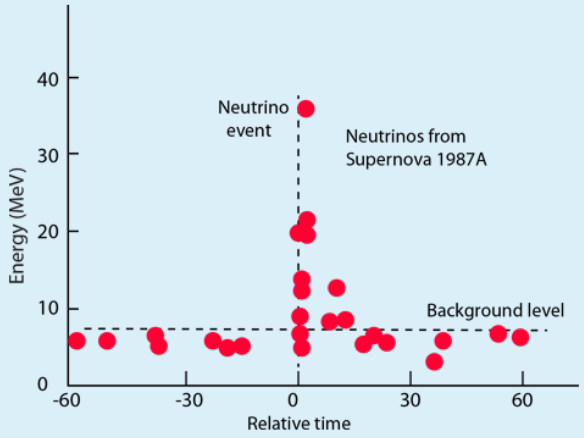
- Information of supernova

- Distance, Direction (so that observers know where to point the telescope)
- And features!

Detection of the features

- Neutrino detection is a rare event
- The incoming data is expected to be Poisson distributed
- Supernova is not the only source of neutrinos in the universe
- Background noise is expected



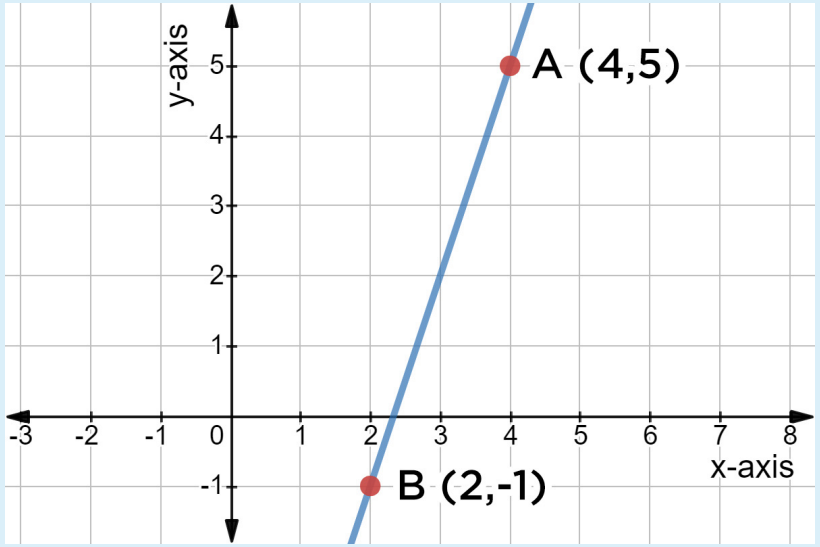


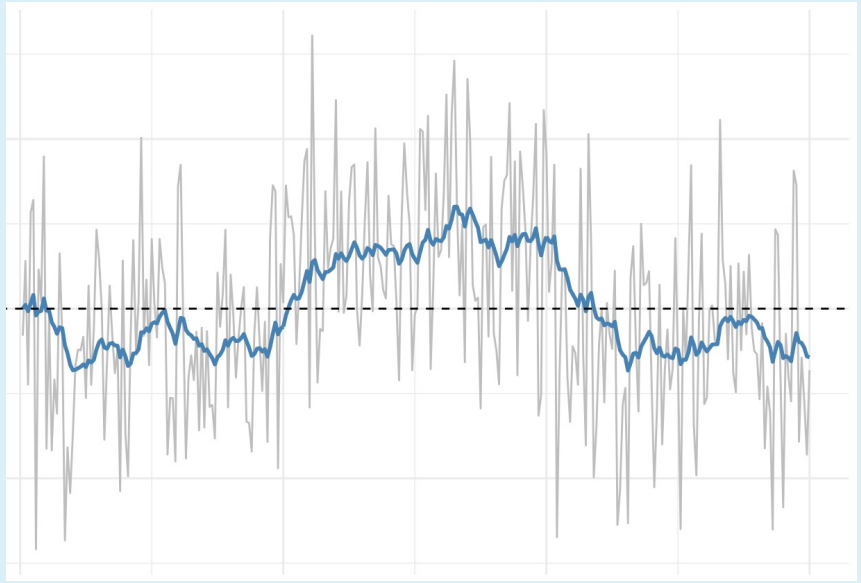
- It is likely that the detection may consist of errors and false alarms
- Target – reduce the rate of these

Algorithms (Secondary peak plugin)

- Simple version
- Detecting rising slope with threshold
- Input: Time series/histogram
- Output: True/False

- Problems:
- False alarms (low threshold)
- Missing features (high threshold)





Algorithms (Secondary peak plugin)

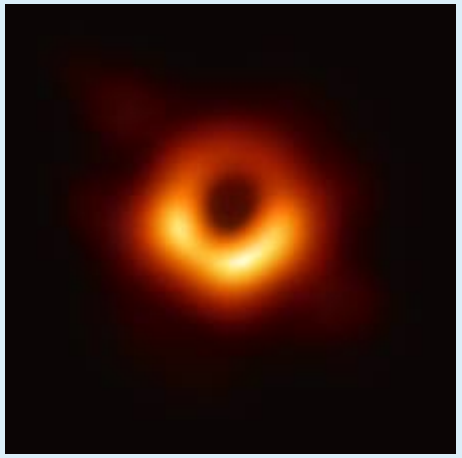
- Utilize the property of Poisson distribution (ongoing)
- Input: Time series/histogram
- Output: Confidence level profile

$$f(x) = \frac{\lambda^x}{x!} e^{-\lambda}$$

- Preform calculation of the data from different detectors
- Compare them according to the relative time after the burst started
- Obtain the time point where second peak occur (with confidence level)

Algorithms (cut-off plugin) By Teammate (**Muhammad Hamza Kalim)**

- Determine if the luminosity of neutrinos drops to background level
- Input: Time series/histogram
- Output: Confidence level value
- Compare the data from detectors



NASA

- Indicating that a blackhole is possibly formed
- All information is trapped – no neutrinos will be further observed
- Failed supernova
- possible detection - through the gravitational wave

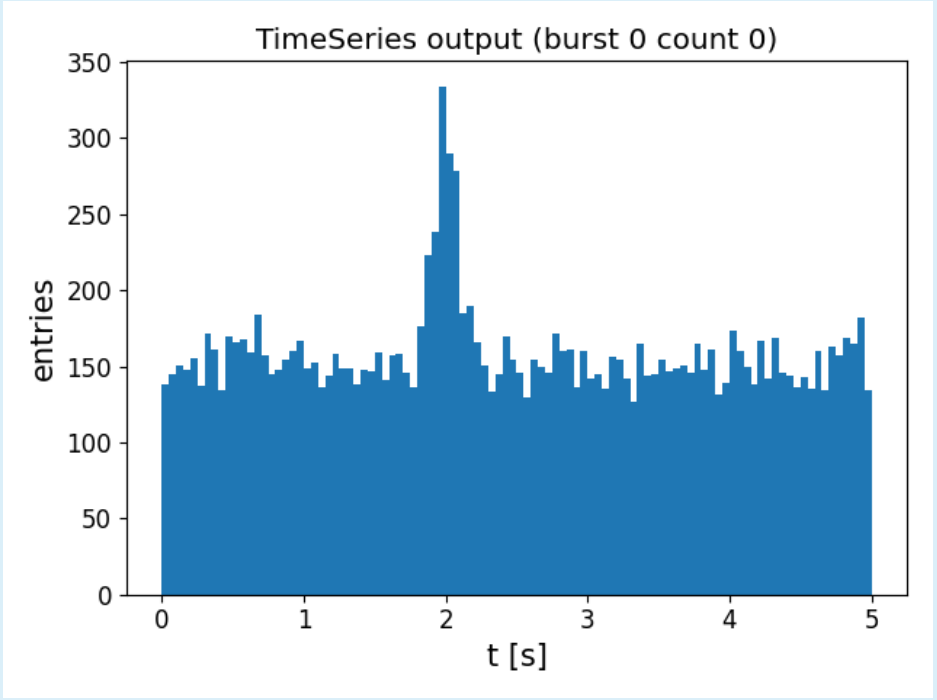
Testing the algorithm

- We need some data to test the accuracy
- Uniform generator + Gaussian generator

- Parameters (bg rate + total neutrinos events of a peak)

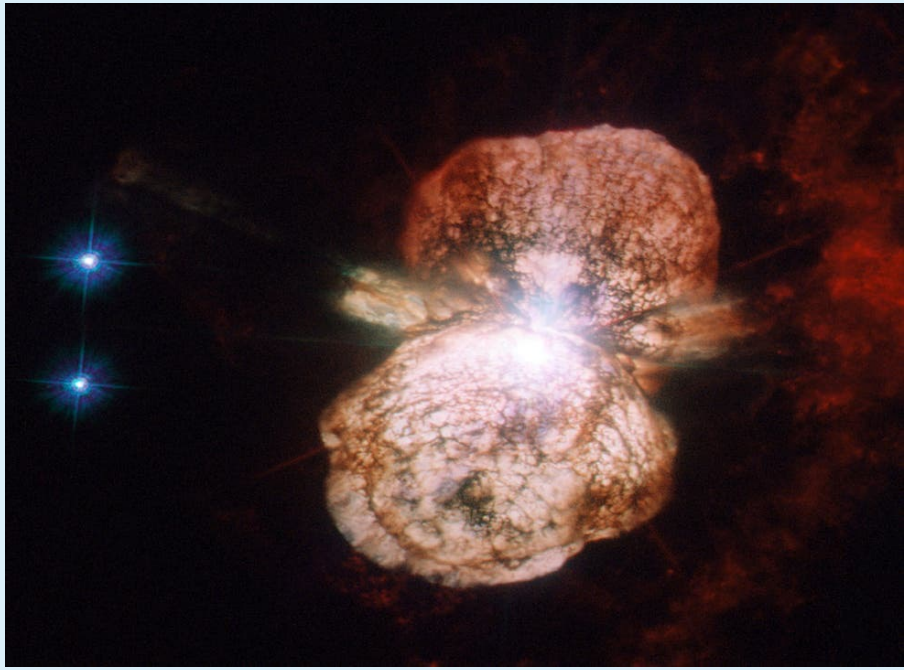
- Simple testing data source

- Able to be massively generated and tested
- Fairly accurate false/missing alarm rate



Expectation

- Supernova occurs
- Get as much information as we can
- Alerts to the observers with description on the supernova to be seen

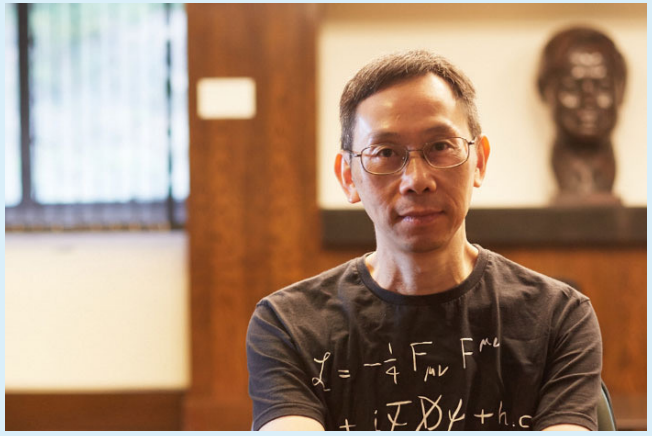


An artistic conception of a supernova explosion
(NASA)

Acknowledgements

- Prof. Jeff Tseng
  - Associated Professor of Experimental Particle Physics in University of Oxford
  - SNO+ team

- Prof. Chu
  - Professor of physics in CUHK
  - Research in Neutrinos oscillations




Q&A