GAGNE: Gamma ray burst Agglomerations and their GeV Neutrino Exploration

Karlijn Kruiswijk (karlijn.kruiswijk@uclouvain.be) on behalf of the IceCube Collaboration

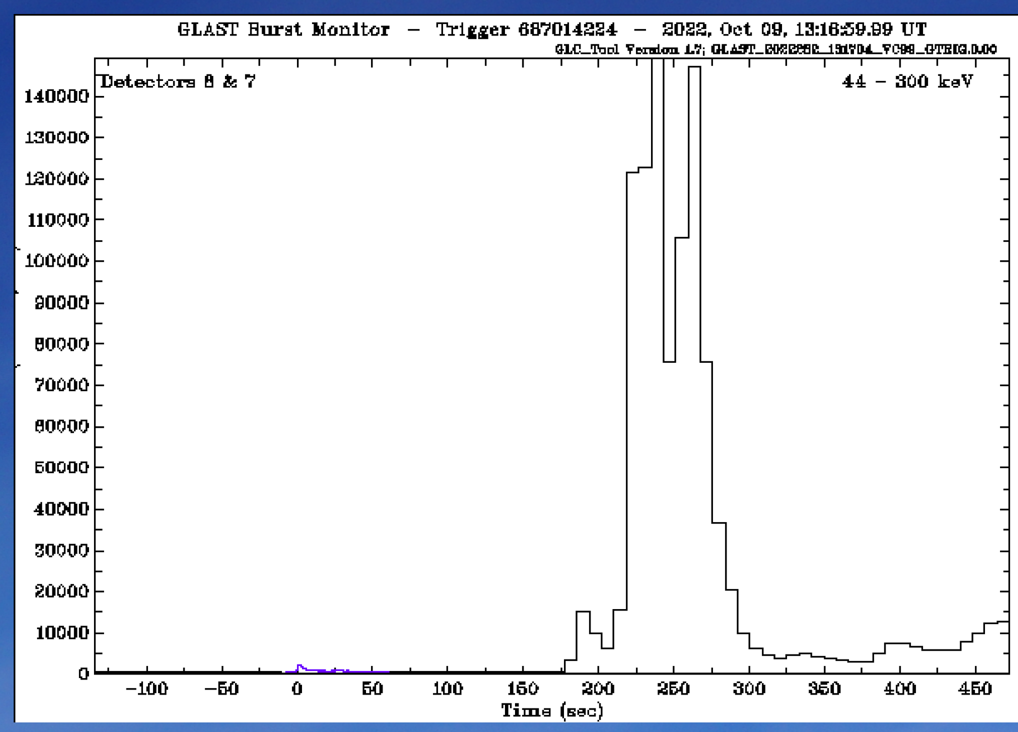
ICECUBE NEUTRINO OBSERVATORY — fnrs FREEDOM TO RESEARCH — UCLouvain

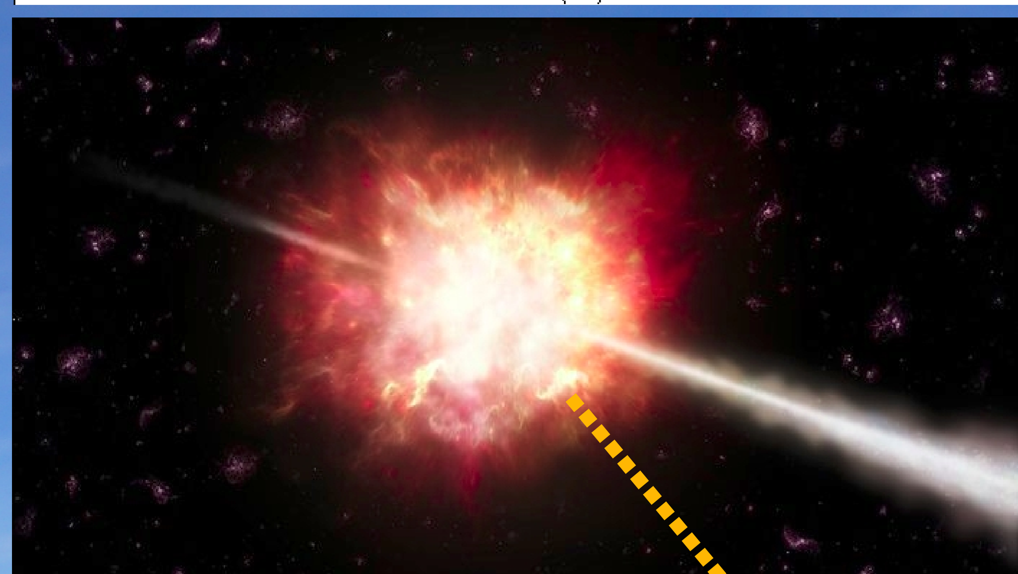
Gamma Ray Bursts and their Sub-populations

While there have been thousands of Gamma Ray Bursts (GRBs) detected, not two of them are exactly alike. GRBs can generally be categorized in two populations: **short or long**, based on the duration of the burst. However, that does not mean that there are only two kinds of bursts possible, and some **sub-categories have been sugested**, like low-luminosity or X-ray rich GRBs.

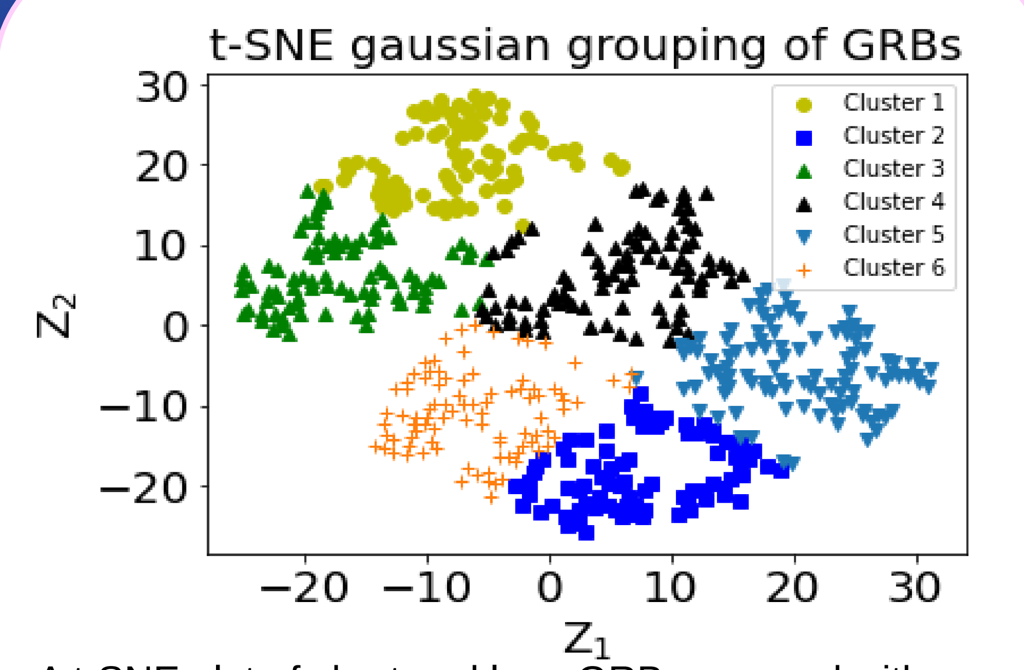
Using the **large catalogues available** nowadays, it is possible to look at the **clustering** of GRBs in phase space to find different sub-populations. These different sub-populations can then indicate different creation processes, with possibly **different neutrino yields**.

Credit: Gwen de Wasseige, IceCube



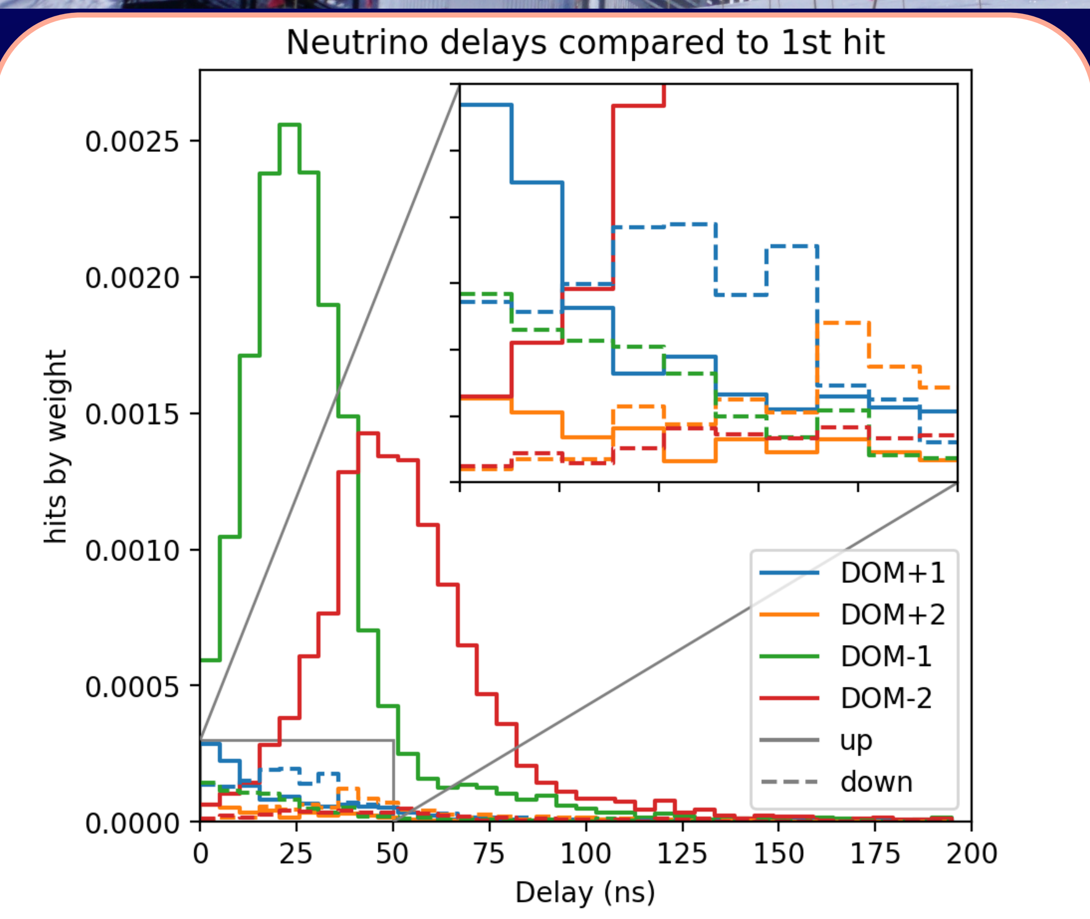


Credit: ESO/A. Roquette



A t-SNE plot of short and long GRBs grouped with a Gaussian mixing model. Cluster 1 contains all short and some long GRBs.

With dimensionality reduction tools like PCA or t-SNE the many variables that describe GRBs can be visualized in a 2D space. In this lower-dimensinality space, clustering algorithms like gaussian mixing models can then be used to group similar GRBs, highlighting potential sub-populations.



The distributions of the delay between the first hit and the surrounding DOMs for upgoing and downgoing events.

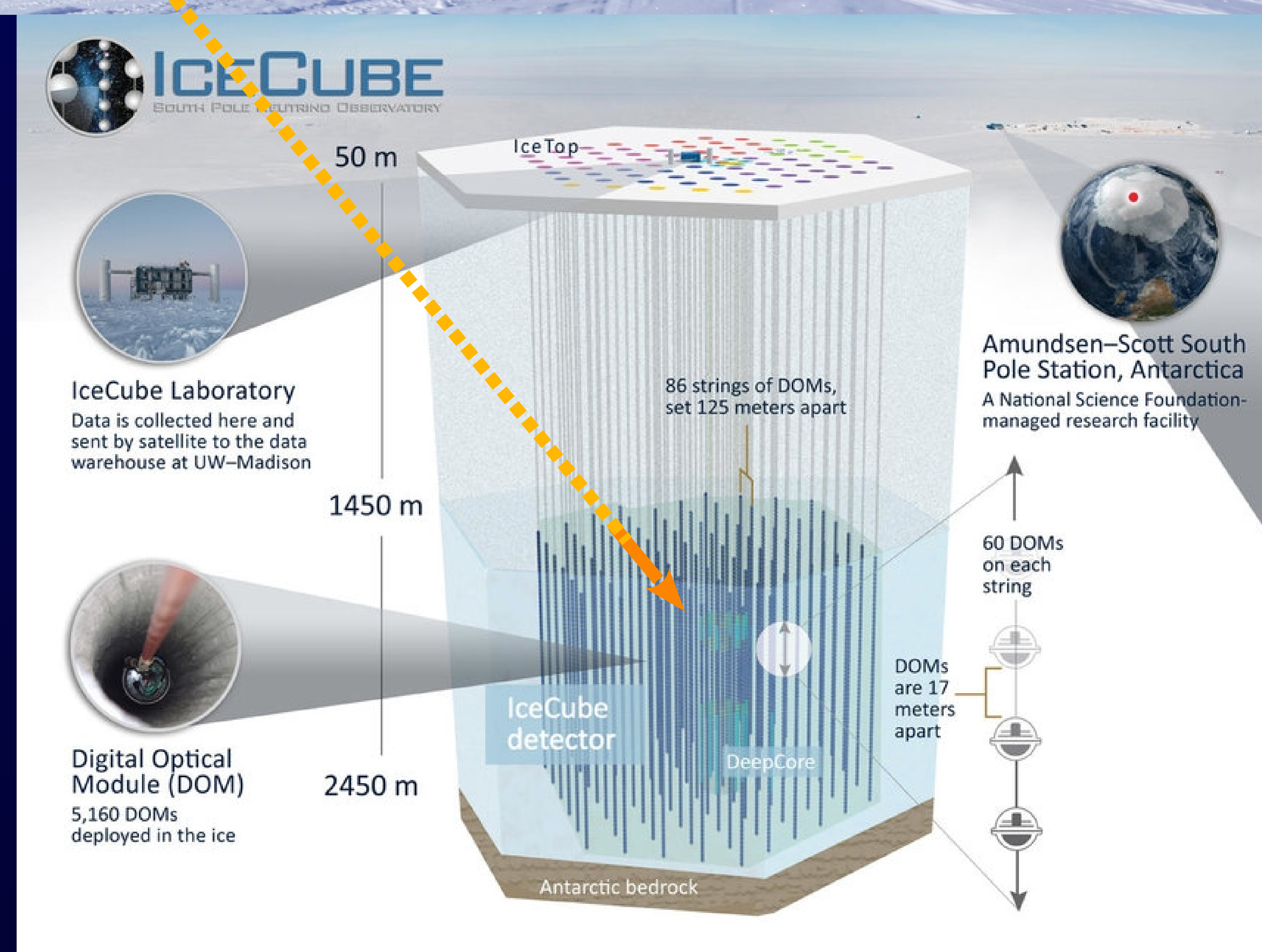
The up/down asymmetry of DOMs can help with reconstructing the direction of neutrinos that normally cannot be reconstructed at all. By comparing the number of hits on a single string and the delays between them, with the help of boosted decision trees, up and down going events can be distinguished.

GeV neutrino Detection in IceCube

IceCube is a cubic kilometer neutrino detector located in Antarctica, built to observe **TeV-PeV neutrinos**. However, with the subdetector called **DeepCore,** it is possible to detect **GeV neutrinos**. This energy region has until now been mostly used for atmospheric neutrinos as they are the dominant contribution, but with the use of **Machine Learning** the sensitivity to astrophysical neutrinos from transient sources can be improved.

Noise reduction is currently done with several different stages sequentially, and will be improved by combining the different stages into one where more optimization is possible.

Furthermore, by using different DOMs on the same string, it is even possible to reconstruct some **directionality** of the incoming neutrinos.

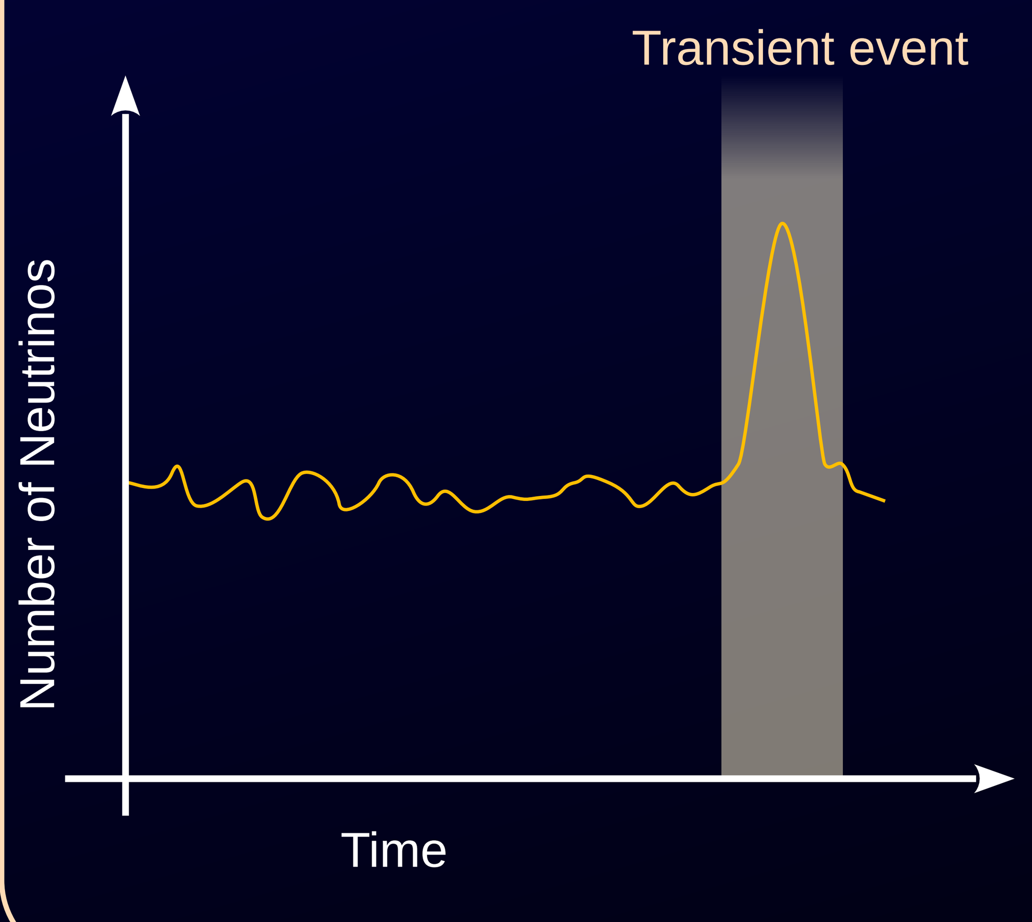


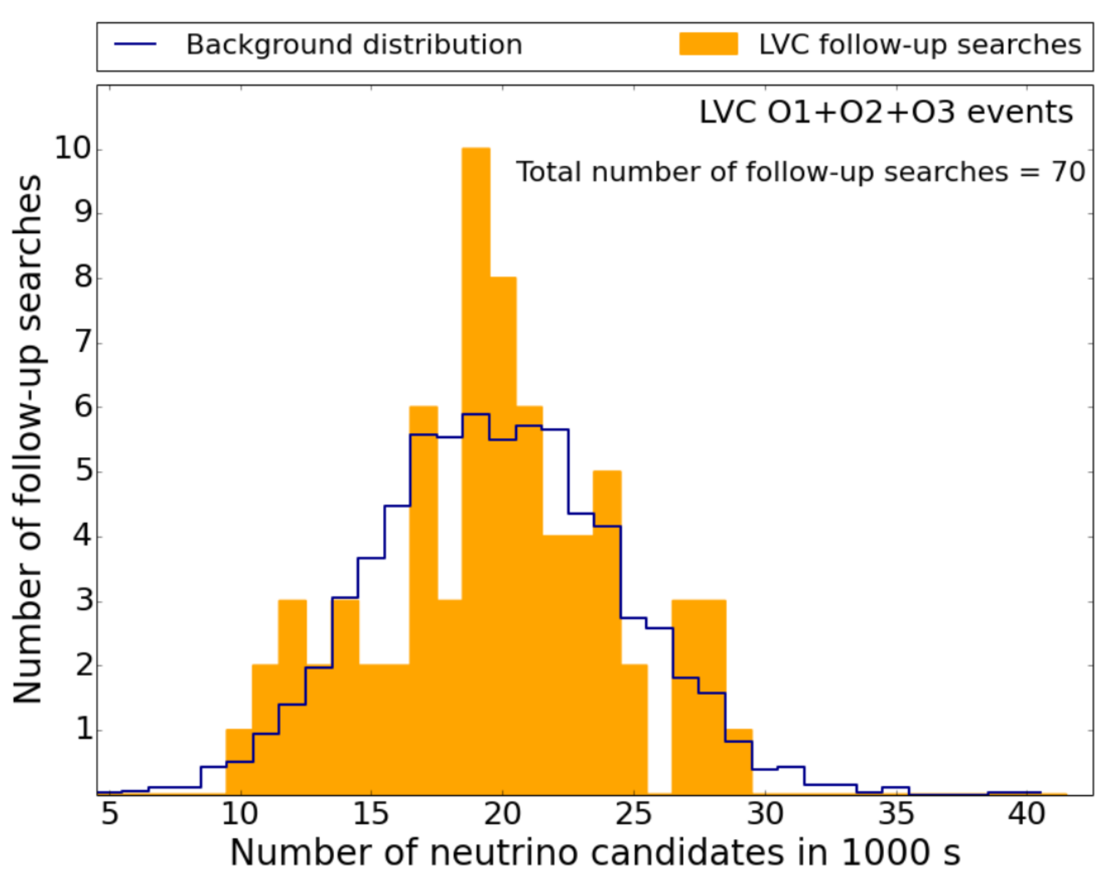
Detecting transient events with IceCube

Transient events have the advantage of having an identifiable time window. Therefore, one only needs to look at a **change in rate** during a transient event to be able to observe neutrinos, which compensates for the imperfect direction reconstruction at these low energies.

The sensitivity can then be further increased by **stacking multiple similar transient events**: where a single neutrino of one transient event, like GRBs, goes unnoticed, several hundred of such events may not.

Stacking the distinct **sub-populations** could push the limit of what has been seen before, by increasing the sensitivity while still taking into account the **diverse population of GRBs**.





The background distribution (blue) and the number of neutrino candidates during individual Gravitational waves (orange) compared to each other as an example of transient events.