



Alert

Alert systems overview

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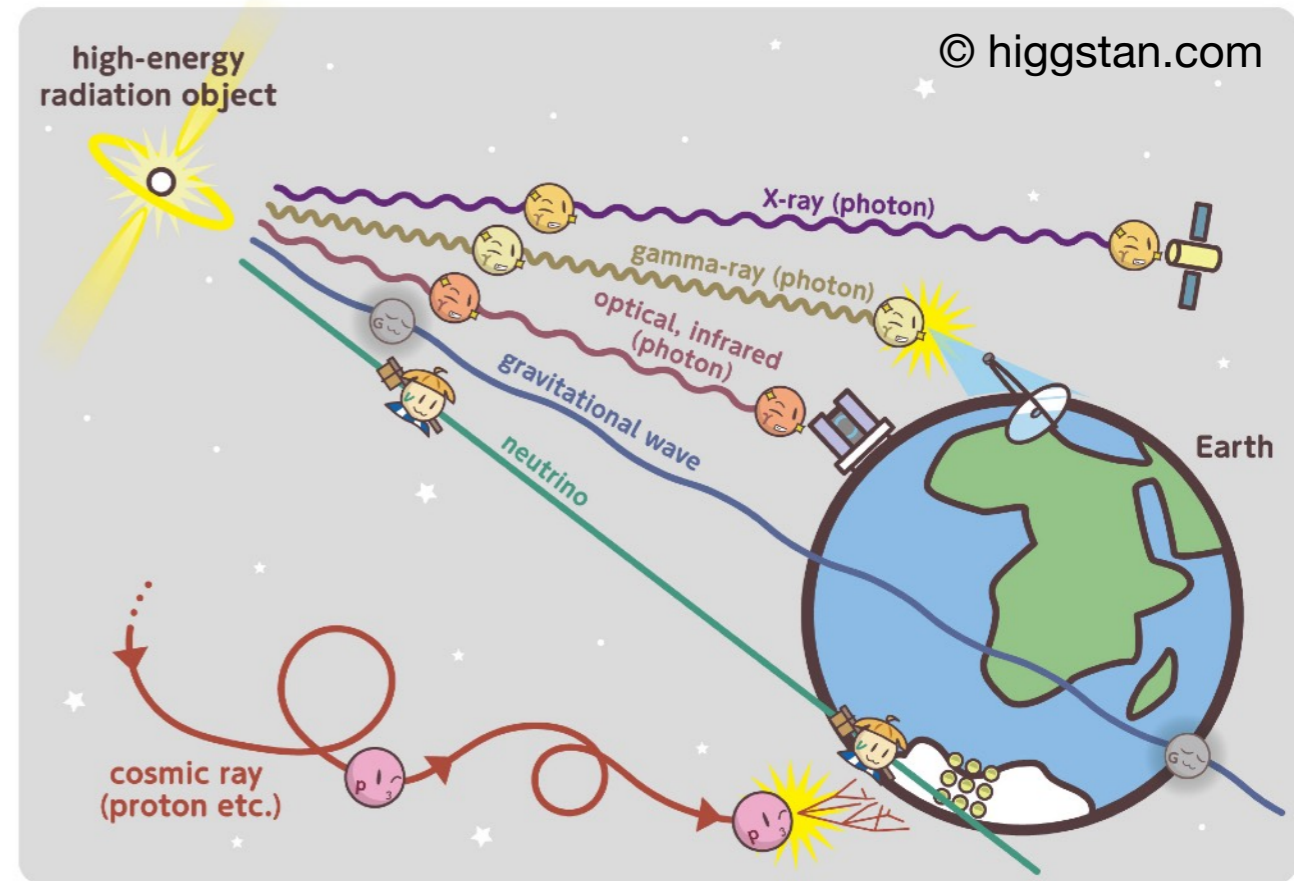
Introduction

We are in *TDAMM* (*Time Domain And Multi Messenger*) era... **What it is?**

- **Time Domain "studies of variability"**
 - (archival) searches of transient phenomena
 - found variable features, to know physics behind (if possible)
 - often not enough,, need to find more and tell others = **alert**
 - Alert makes sense only with reactions = **follow-up observations**
 - to find similar features of known sources
 - and more: new phenomena and/or new sources
- **Multi-Messenger "full set of available info"**
 - Photons: Energy (wavelengths = MWL), flux (fluence/duration), direction (morphology), polarization, etc.
 - Neutrinos: E, direction, event type (flavor), flux (1 or more), etc.
 - Gravitational waves: direction, event type (BBH/BNS), mass, etc.
- **Two separated concepts, which are in reality strongly related**

TD meets MM

- Historically, "single messenger" Time Domain came earlier
 - Optical (Novae, SNe,,,), X (TDE, XRB,,,), Radio,,,
 - MWL studies of GRBs
 - GCN since 1992 (BATSE).
See Sakamoto-san's talk
 - FRB, optical TDE, etc. are newer examples of single messenger TD
- SN1987A was the only TDAMM example for decades
 - SNEWS (SuperNova Early Warning System) since 1999
- Breakthroughs in 2017: GW/GRB and IceCube neutrinos
 - **Gravitational Waves (GW)** is made in a transient phenomenon, so connected with variability from the beginning = **Clear TDAMM case**
 - while **neutrino** sources can be steady or variable. We need to be careful to **distinguish variability from fluctuations**



Strategies

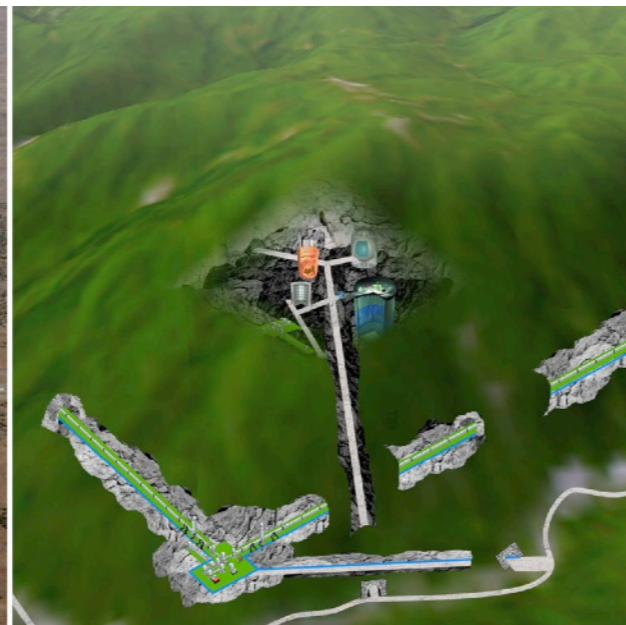
- Big amount of statistics **vs.** rarer cases
~ = expectations **vs.** serendipity (unexpected!)
~ = biased targeted strategy **vs.** no/min. bias for underlying evts
"neutrinos from blazars?" vs. "unknown neutrino emitters?"

- Matter of balance. Both needed.
Should not mix, but not a fight...



- The alert (trigger) side and the follow-up side should match with a single strategy (or 1-to-1 corresponding strategies)
 - Follow-up needs to understand what is (not) sent as alerts
 - Alert needs to understand what is (not) useful for the other

Alert (trigger) side



Alert (trigger) side

- What to find and send

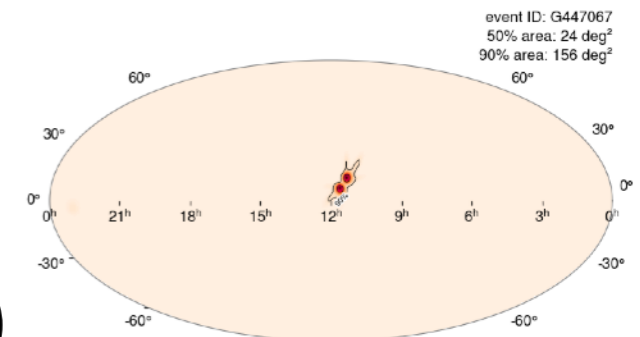
- Feature to trigger (time, flux/number, types, energy,,)
- Direction / localization (error contour)
- False Alert (or Alarm) Rate (FAR)

- They are highly correlated

- Localization depends strongly on trigger types
- Good localization is not always high prob. of being from the center. The error contour is unnormalized/conditional PDF

- Ex.) GW S231018cb: 50%-error of 24 deg², but Terrestrial (noise) Probability of 0.84

- **"Error contour divided by FAR" is (ideally) closer to the normalized PDF. Can it be useful?**



More on FAR

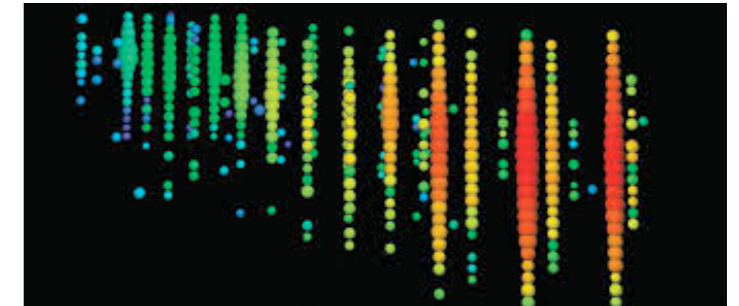
How much can we accept waste of our efforts (none? :))

- "Efforts" are not only observation. If 'false' is known
 - **before follow up**, we can stop to trigger the ToO obs.
 - E.g., GW alerts are sometimes retracted, which is circulated via GCN Notice typically <1 hr later
 - **after follow up**, we do not need to discuss the results
 - E.g., a technical problem on Swift caused fake alerts, to be announced later (hrs? as far as I remember) in GCN Circular
 - E.g., revisions of IceCube alerts (typ. hrs later) w/ a huge error
 - **months/years later, or not forever**, we need to include this possibility in the discussions (and papers)
 - E.g., track muon neutrino alerts always have a significant (typ. O(10%)) probability of being not astrophysical
- We cannot avoid the lower, so just need to be ready

Case study: IceCube alerts

- **Singlet**

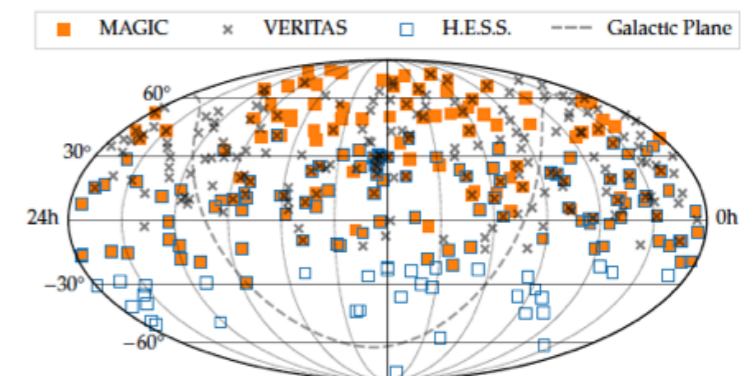
- Muon neutrino w/ small error is a good target if w/ high signalness (mild FAR), but **does not mean high variability. No need to react fast**



- Cascade from electron neutrino, w/ high signalness (low FAR) but a large error. Probability to catch something is low.

- **Multiplet**

- Correlation with a pre-selected source list
Pros: smaller no. of trials ($O(10)$), variability
Cons: bias, "expected" from known sources

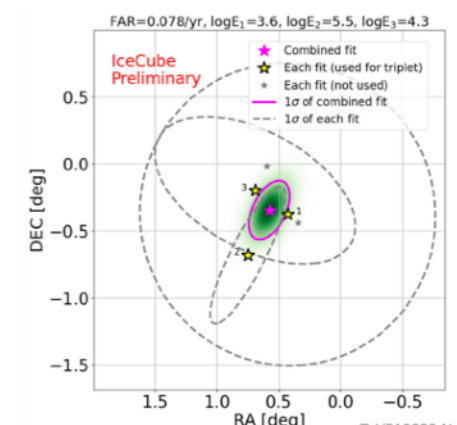


K. Satalecka+, PoS(ICRC2021)960

- **Update the list to reduce the bias, by keeping the small trials**

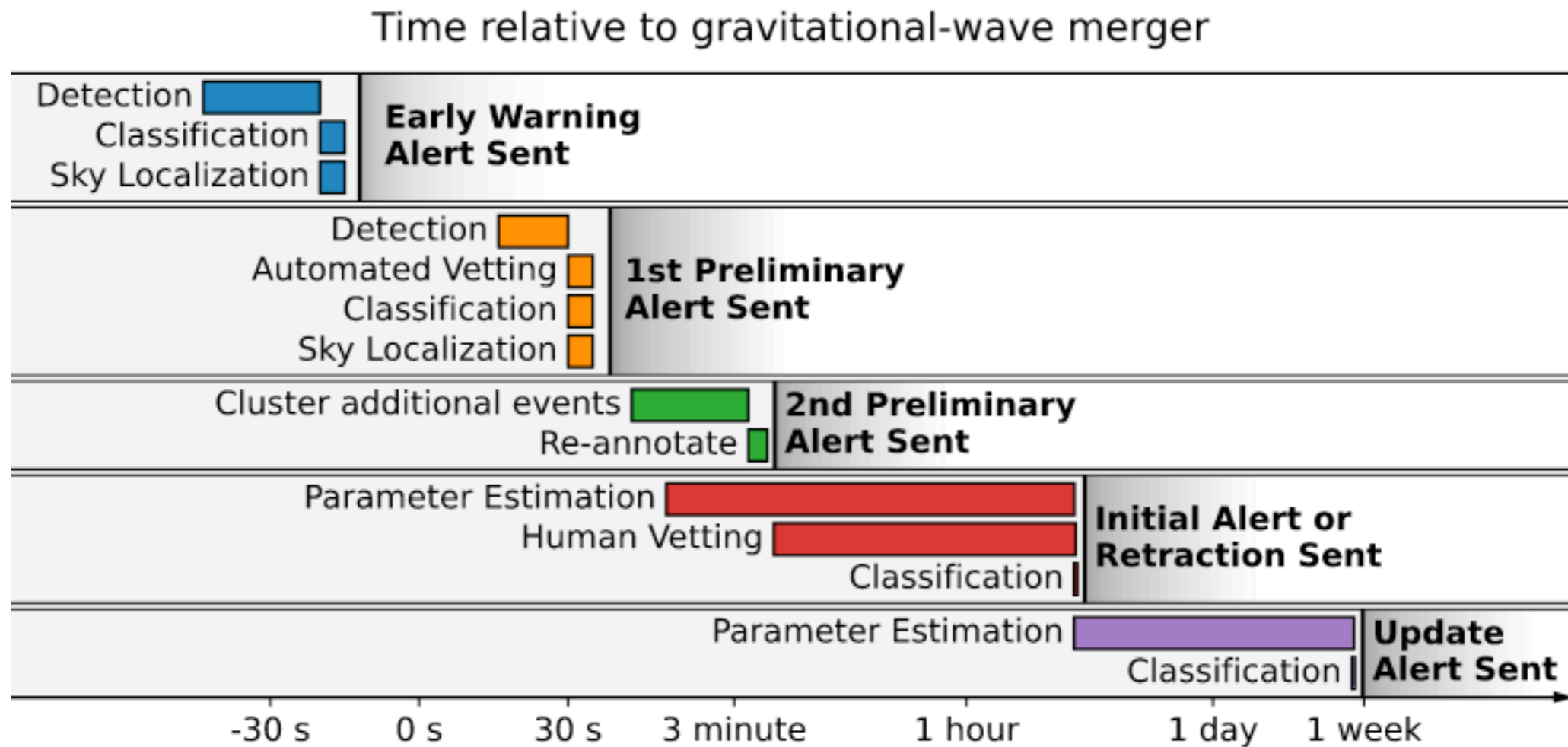
- Without any predefined list
Pros: serendipity from unknown source
Cons: huge no. of trials ($O(1000)$), low significance

- **Use a different logic to pick up more "hints"**



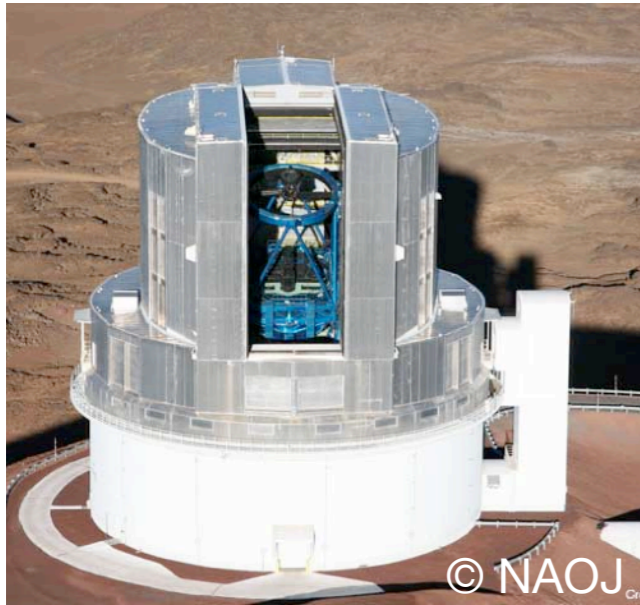
N. Shimizu+, TeVPA 2023

Case study: LVK alerts (to be skipped)



from <https://emfollow.docs.ligo.org/userguide/index.html>

Follow-up side



Follow-up side

- **Pre-select** what to react & **(more difficult) what not to**
 - We cannot do all. React only if matching "our" strategies
- If a to-be-reacted alert comes, react (automatically/discuss) according to **localization and FAR at the same time**
 - A good localization is only a necessary condition.
Need also a low FAR / high significance (but see next)
- Most of the cases, follow-up side know much better what / how to observe, so discuss & re-adjust the strategy internally
 - "Nearest 4FGL..." in alerts is often misleading. Be careful :)

Pre-trial vs. post-trial

Last but not least: **significance is pre-trial or post-trial?**

- Q. "What is trials in our cases?" (FAQ for VHE GRB hints...)
 - (I think) a matter of policy. If we knew the individual triggers as different guys, we should NOT count them as equal trials, even if it is conservative (it is too conservative)
 - Our answer "only observed (tried), long GRBs"
- Depends on the alert types. From IceCube case study,
 - $O(1000)$ for all sky: should be corrected for $\sim 4\pi$ / error
 - $O(10)$ with a pre-selected source list: depending on the source types, e.g., no. of **blazars in the list** (not from all sky...)
- but,, the alert side (like IceCube) might not know that blazars and SNRs are different, and tend to count them as equal trials.
So,, it should be discussed in advance in the follow-up side (ideally. In reality it often happens just after the alert came...)

Summary: Take-aways

- **The alert system we often think is a part of the whole business. The alert and follow-up sides should match**
- **MM era increased the discrepancy between the two. Try to understand the other for a common strategy**
- **Localization error and FAR (\sim significance⁻¹) require a careful interpretation for the follow up observations**
- **It requires discussions in advance in the follow-up side, as the policy and understanding are different**