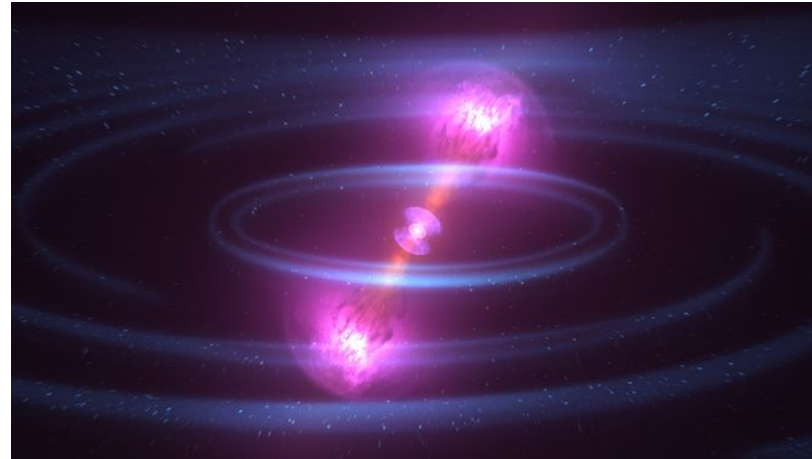


# ET in multi-messenger era



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IJCLab

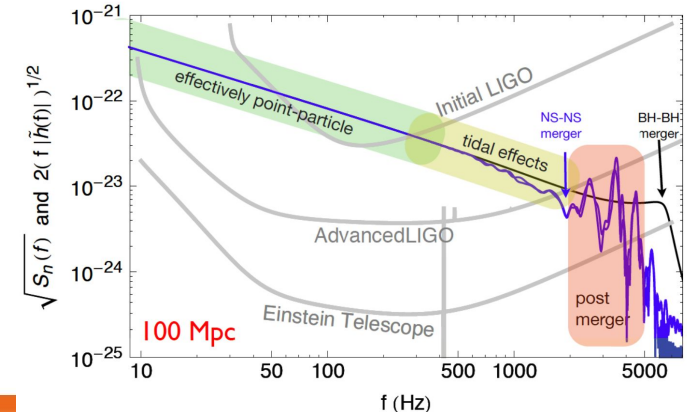
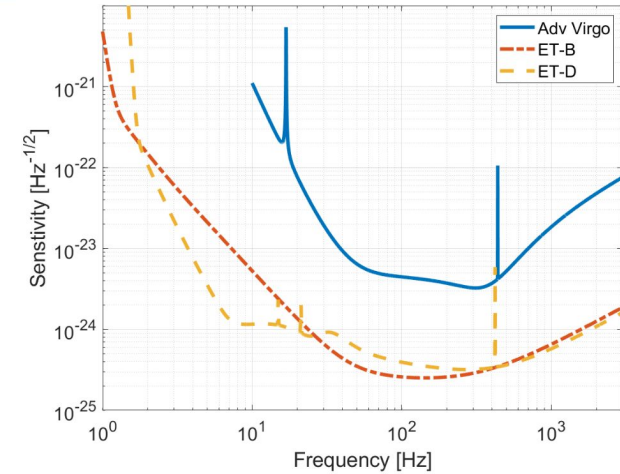
Only one GW event with EM counter part so far with lot of physics !

ET will improve by a factor 10 the sensitivity of Advanced detectors

BNS post merger signals accessible :

- new constraints on neutron star equation of state
- evolution of the post merger
- link with short gamma-ray bursts

Expecting also core collapse supernovae signals  
Need high duty cycle !

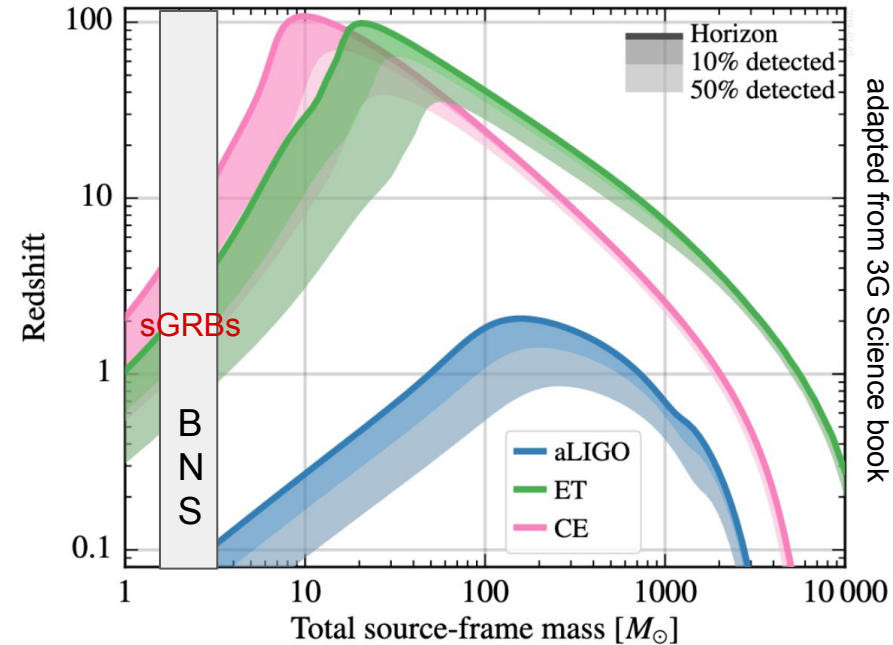


## Large increase in sources detectable per year

BBH  $\sim 10^5$  to  $10^6$  / year

BNS  $\sim 10^4$  / year - among which 10 - 100/year with EM counterpart detectable

- BNS signal up to 10 hours in the detector (Nitz and Dal Canton 2021) -> early alert will be an important aspect for follow-up
- Overlap with many BBH signals
- Contamination between signals - PE estimation could be more challenging in some cases (Samjdar et al - PRD 104 (2021))



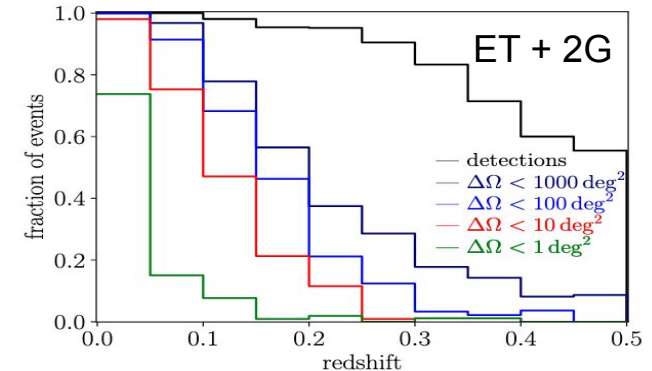
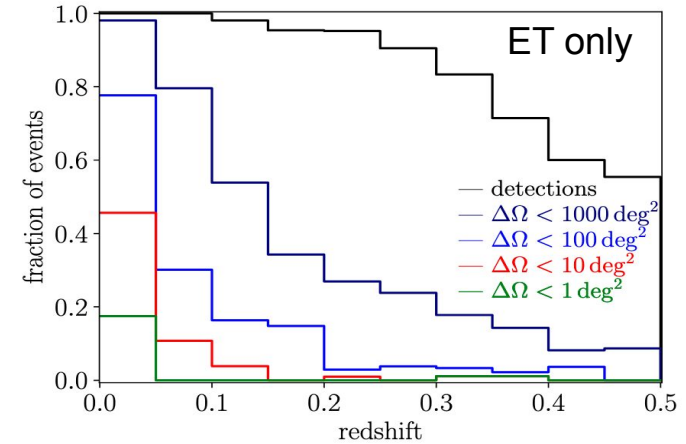
## Needed to localized event to find counterpart

ET alone will be able to localize to few deg<sup>2</sup> very closed-by events

can be improved with 2G detectors, even better if thinking of a 3G network

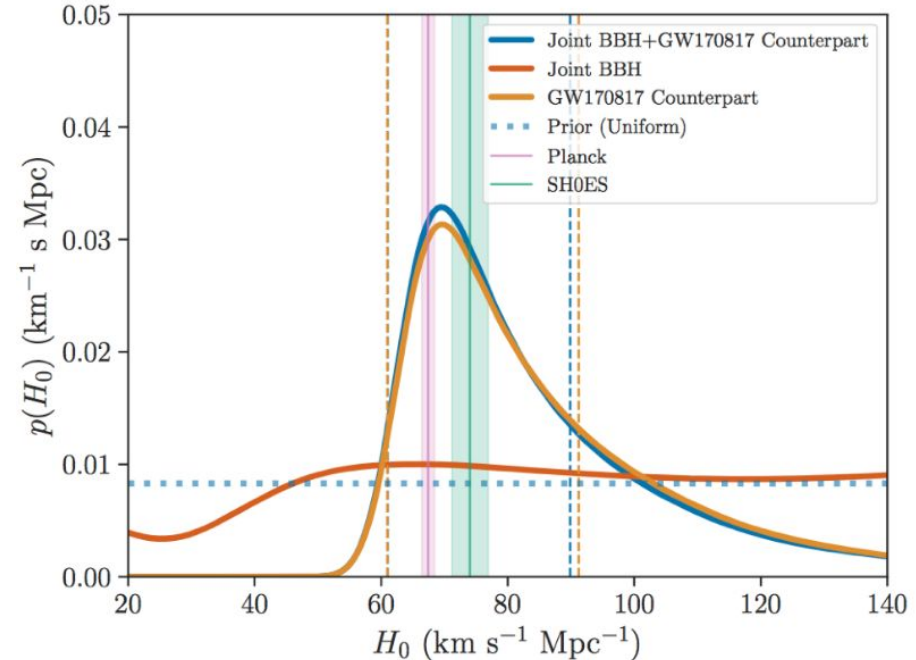
for BNS, need to take into account the rotation of the Earth

May be able to have warning few hours before the merger



## GW provide cosmological scale

Constraints on different parameters  
 with  $\sim 600$  BNS-EM detection we  
 can reach Planck resolution on  $H_0$   
 even with BBH we can have  
 constraints to few % level



## Transient sky is changing rapidly

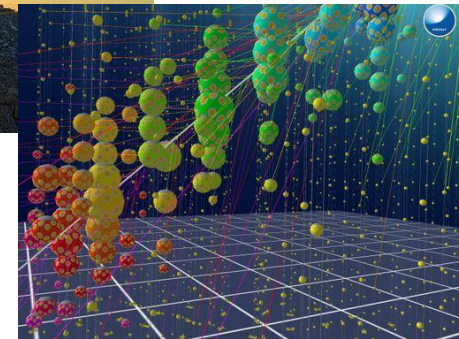
Lot of new facilities and running at time of ET :

SKA ~1000 FRB/day

LSST like instrument - 10 millions alerts/night

ATHENA, CTA, ELT, James Webb telescope, ....

Neutrinos detectors like KM3NET or IceCube 2G  
- tens of events/day ?



**Will need to react quickly to perform follow-up**

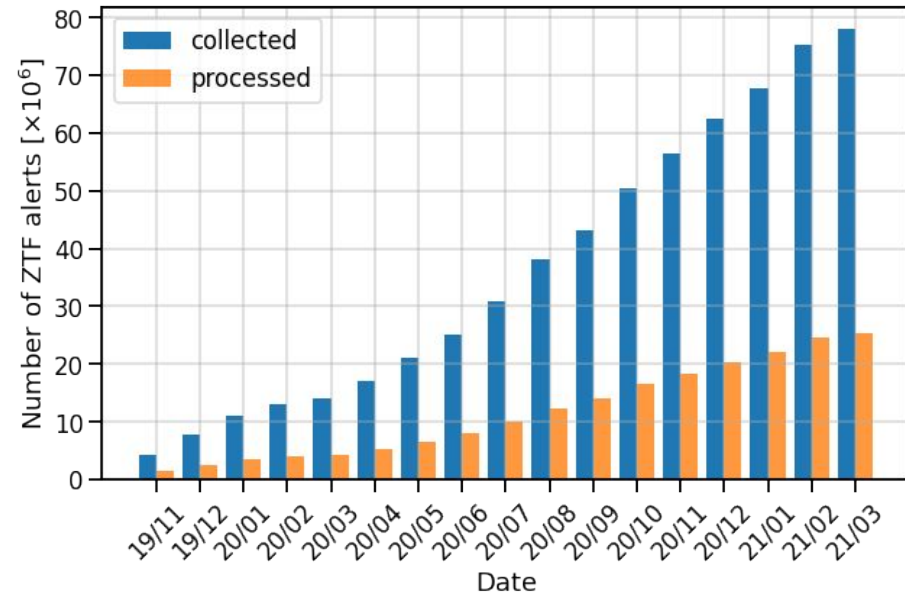
## The deluge of alerts for MMA have started

With the advent of deep and fast surveys, the number of alerts per night has exploded.

Current surveys like the Zwicky Transient Facility already produce hundreds of thousands alerts per night.

Rubin Observatory (2024-2034) will send ~10 million alerts per night.

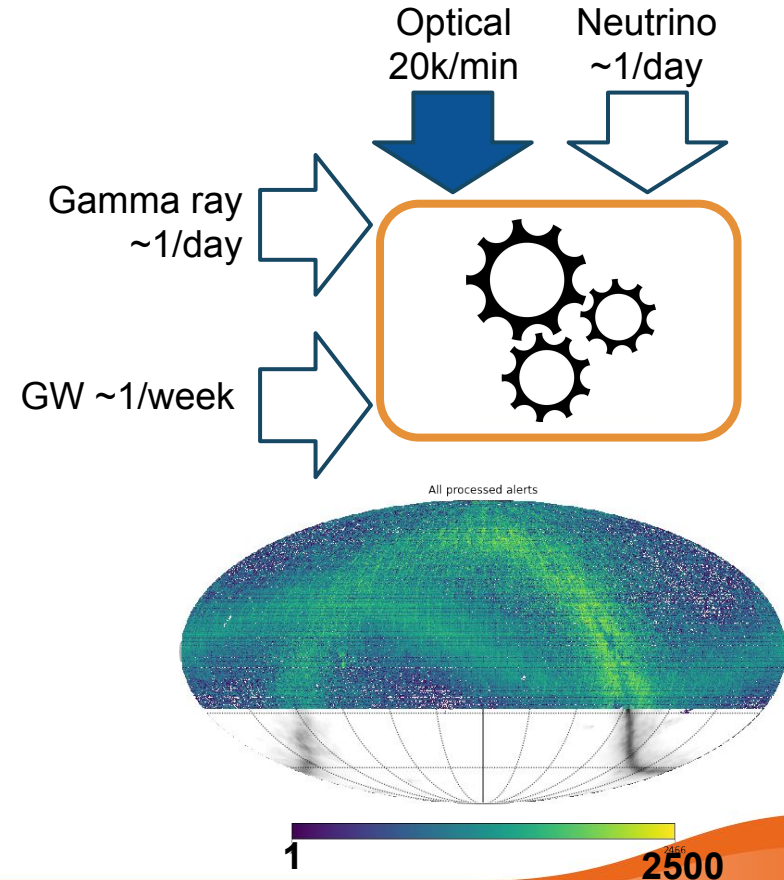
Cumulative - Fink Rubin broker - 2021



## The first step is to find the needle in the haystack

How to select counterpart candidates in a fast and reliable way?

- Visual inspection of all candidates within the error box is no more an option.
- The community relies on *broker* systems to collect, filter, process and redistribute alerts of interest at scale, and *marshalls* to visualise data from multiple sources.

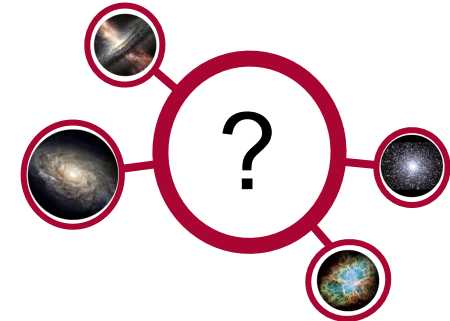
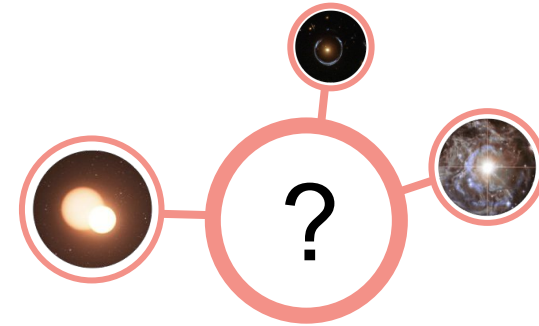




## The first step is to find the needle in the haystack

The use of Machine Learning techniques and cloud computing is becoming more frequent.

- Dedicated center like CC-IN2P3/INFN Bologna to process data live every night/day.  
note US is more on private cloud facilities  
quid on European side ? develop shared and public solutions ?
- But ML is not magic and domain knowledge remains important, will still need humans in the loop
- Team to bring knowledge from a large panel of messengers and frequencies



## Network of follow-up telescopes will be key

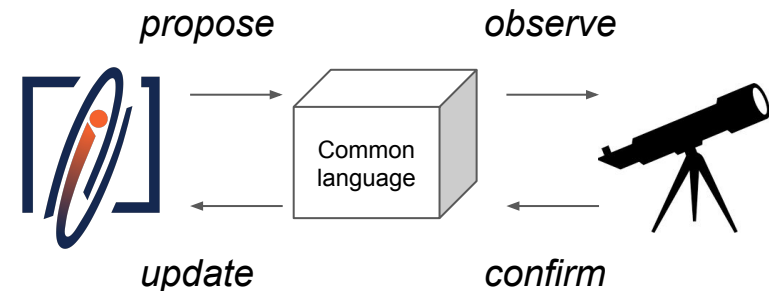
In order to quickly respond to an event, one needs to be able to easily communicate.

To optimize operations, interoperable tools and standards should be enforced (observing plan, data format, data content, transport protocol, ...), e.g. VO protocols

Coordination and *operating modus* should be defined **before** operations start.



GRANDMA network of telescopes 2021



## Einstein Telescope will be a major actor in MMA !

ET will scan a large fraction of the observable universe

Lot of physics interesting when being able to observe the event with others messengers

Large number of alerts both for GW and EM parts - will need both AI and humans

Need to use new technologies to deal with these flows and perform correct filtering - already in preparation for LSST like observatories