Considerations for third-generation networks

3G Science Case Networks Group

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Questions about 3G network parameters

How many detectors?

Where to place detectors?

What types of detectors?

L, triangle, hot, cold, etc.

How long to keep 2G detectors online?

How many detectors?

Source triangulation argument:

- Three detectors localize to an ellipse on the sky
- Important for multi-messenger studies (e.g., BNS at $z < 1$)

Polarization / PE argument: (e.g., Gürsel & Tinto 1989)

- GW source has four unknowns: two sky angles, two polarization amplitudes
- GW detector network gives N amplitudes and $N - 1$ timings
- ≥3 detectors needed to disentangle polarization information from sky location
- Important for all systems, even at high redshift

Where to place detectors?

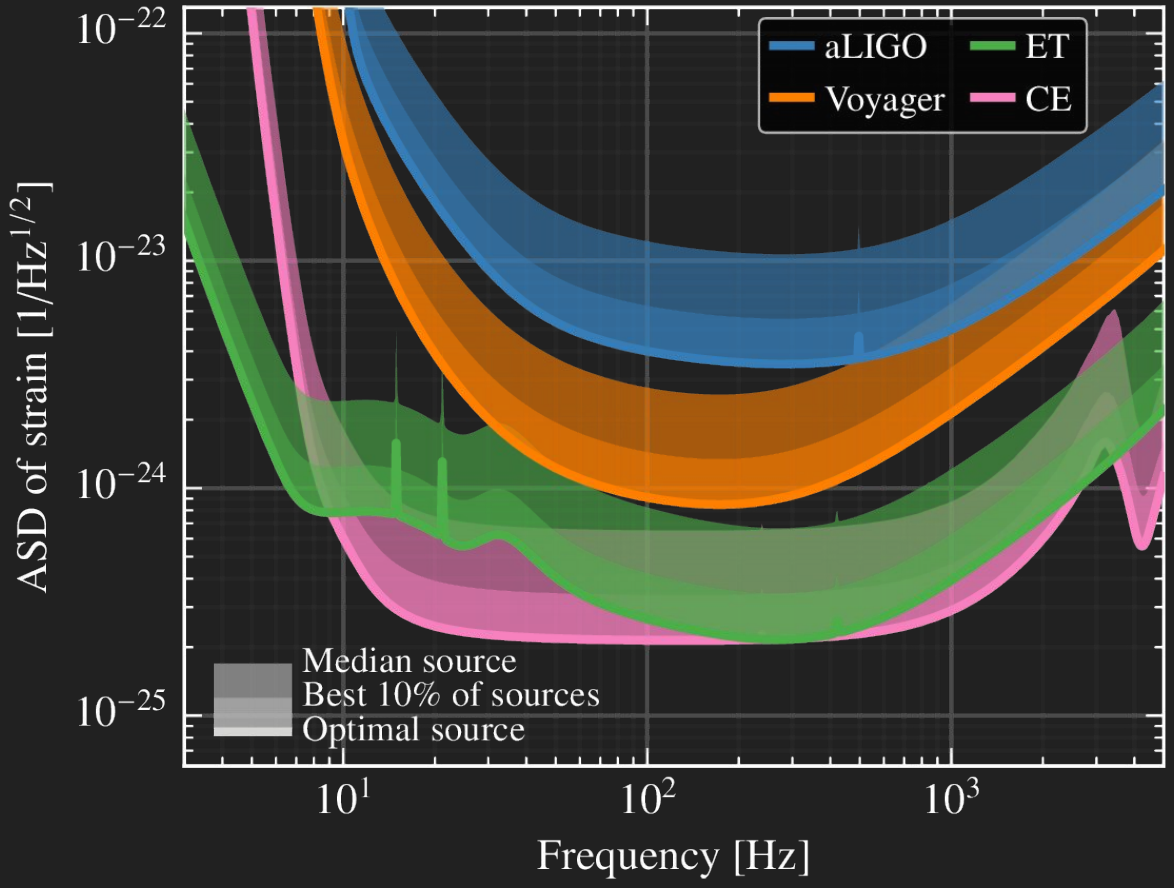
Widely separated (for timing resolution)

Oriented for good polarization sensitivity

Highly constrained by geography, geology, politics, etc.

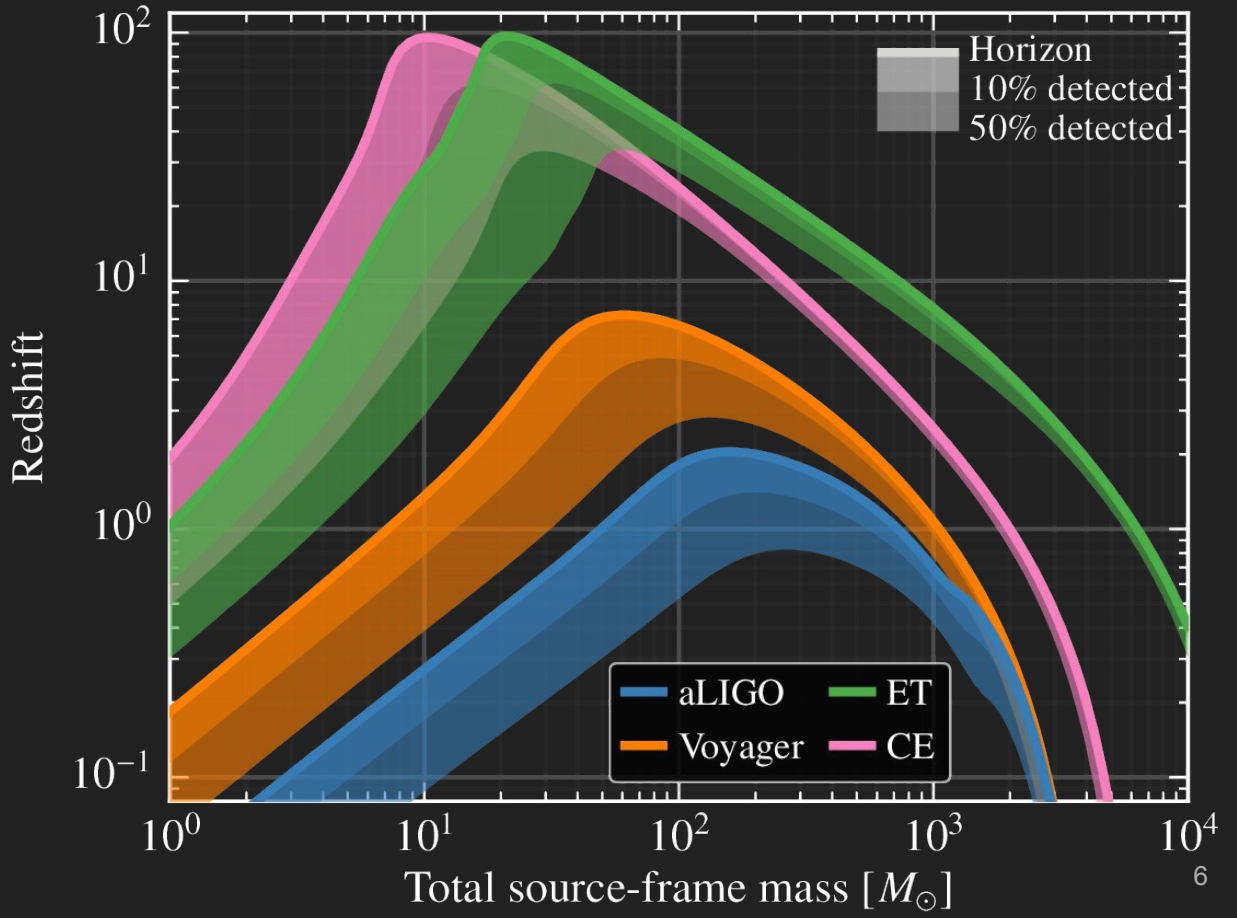
What types of detectors?

Effective strain for an ensemble of monochromatic sources distributed isotropically in sky location and inclination



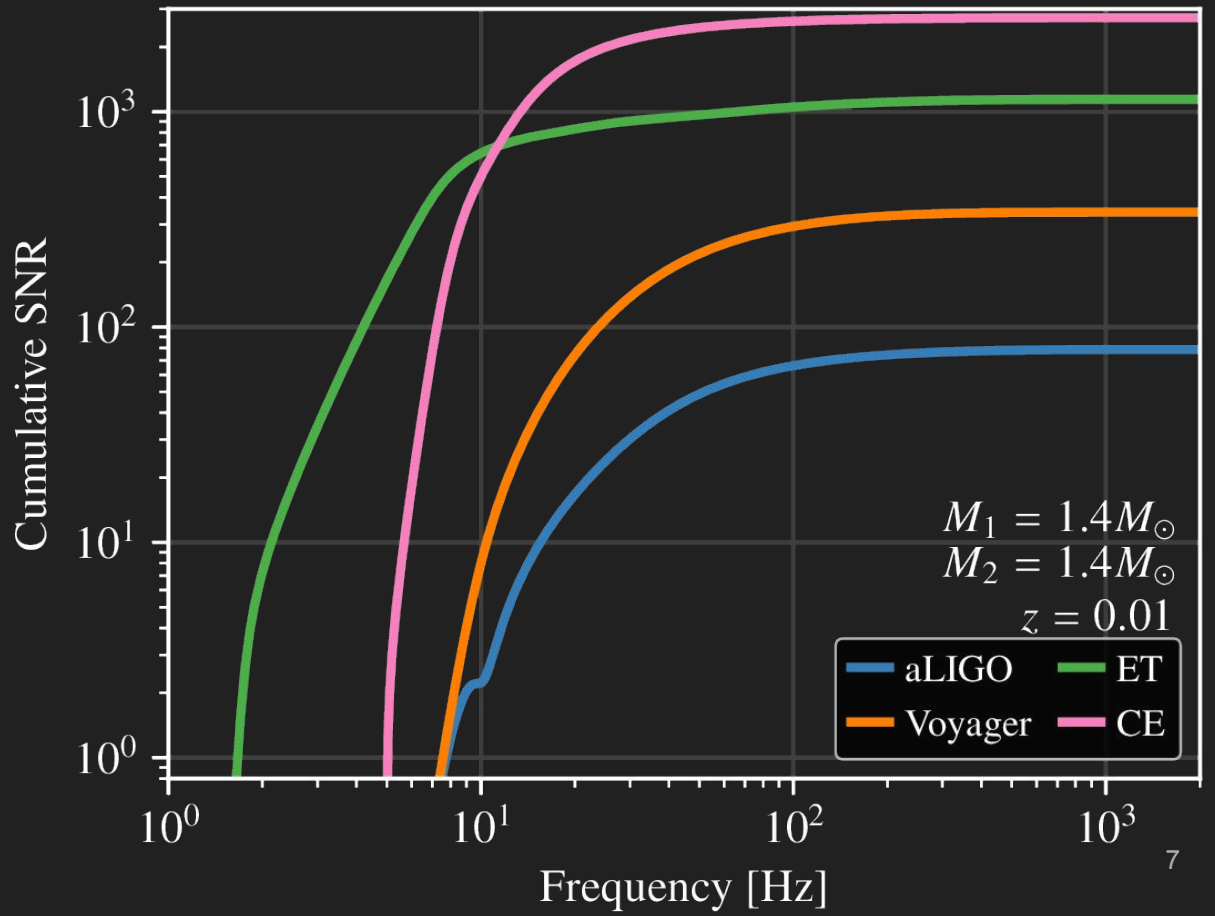
What types of detectors?

Ensemble of equal-mass nonspinning binary black holes, distributed isotropically in sky location and inclination



What types of detectors?

For an optimally oriented source...



Network performance metrics

Want to connect network/detector parameters to science goals in a sane and quantitative way

Identify a limited number of performance metrics shared by multiple science goals

> *E.g., localization/distance uncertainties for binaries, high-frequency sensitivity for NS postmerger or supernovae*

Should we optimize the golden events, or the average event?

Some previous work on network performance metrics

Raffai+ (2013), Hu+ (2015): metrics-based optimization of 3G facility placement

Vitale+ (2017), Vitale+ (2018): parameter estimation for black hole binaries with selected 3G networks

Mills+ (2018): sky localization with selected 3G networks

Michimiura+ (2018): optimize the 2G BNS sky localization by tuning Kagra noise curve

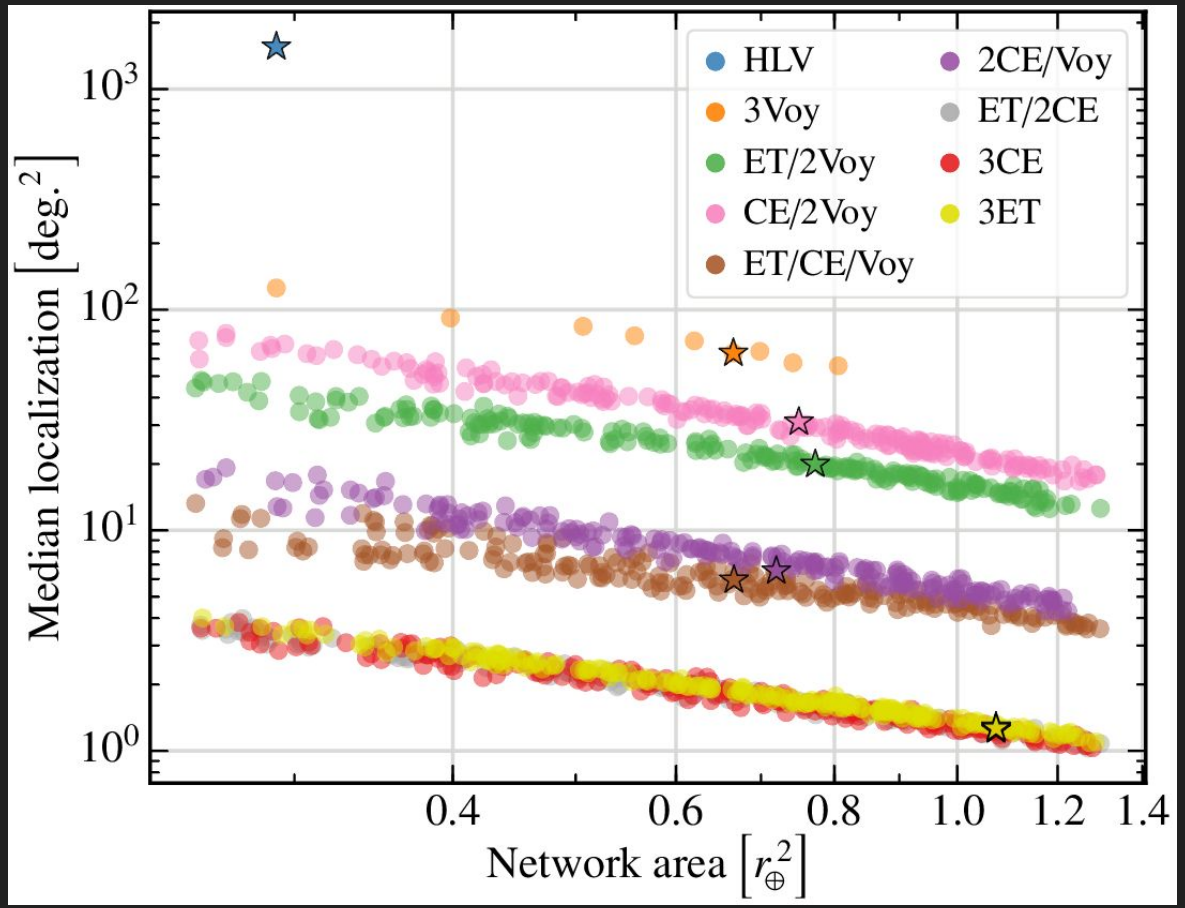
Please send us any others you think should be included in the report!

Example metric: BNS localization at z = 0.3

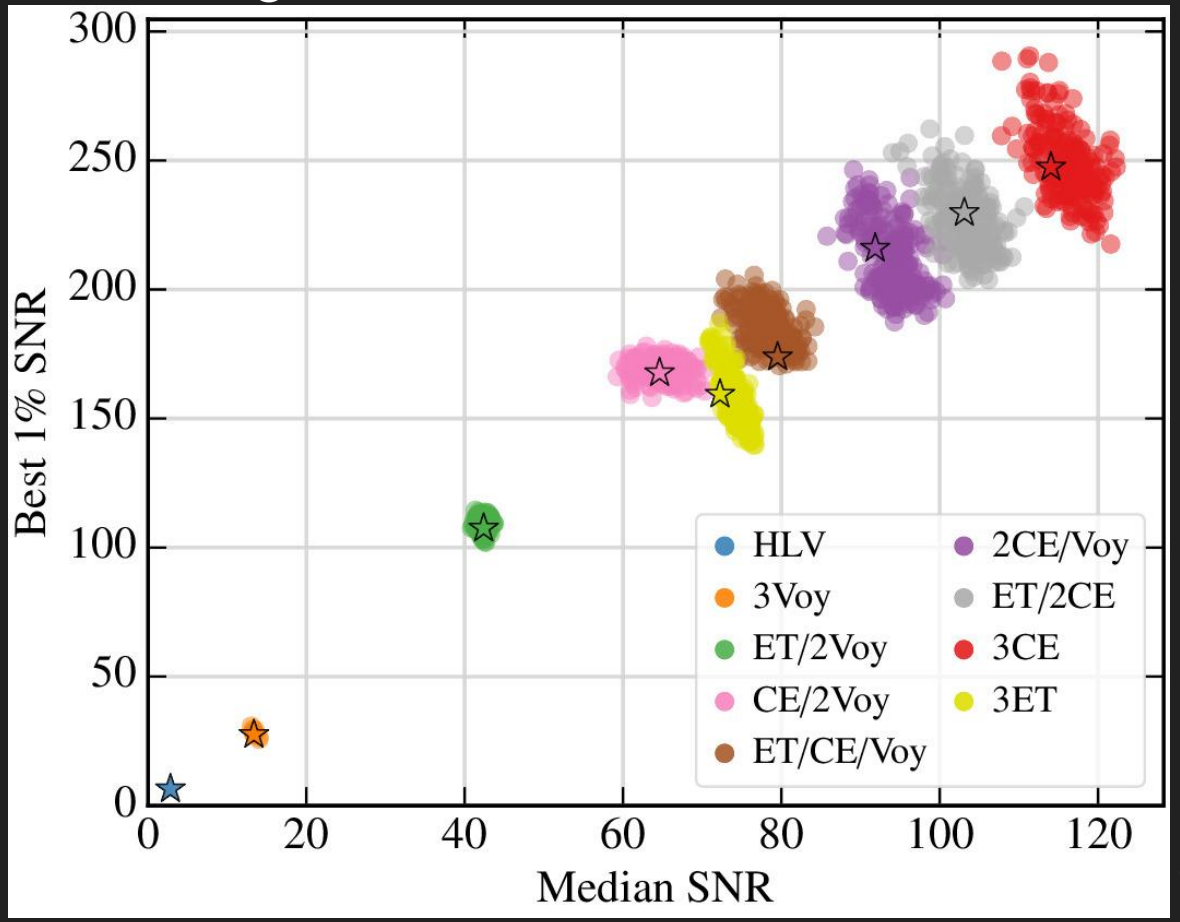
Fisher matrix analysis (à la Bayestar)

Circles: networks with random facility locations

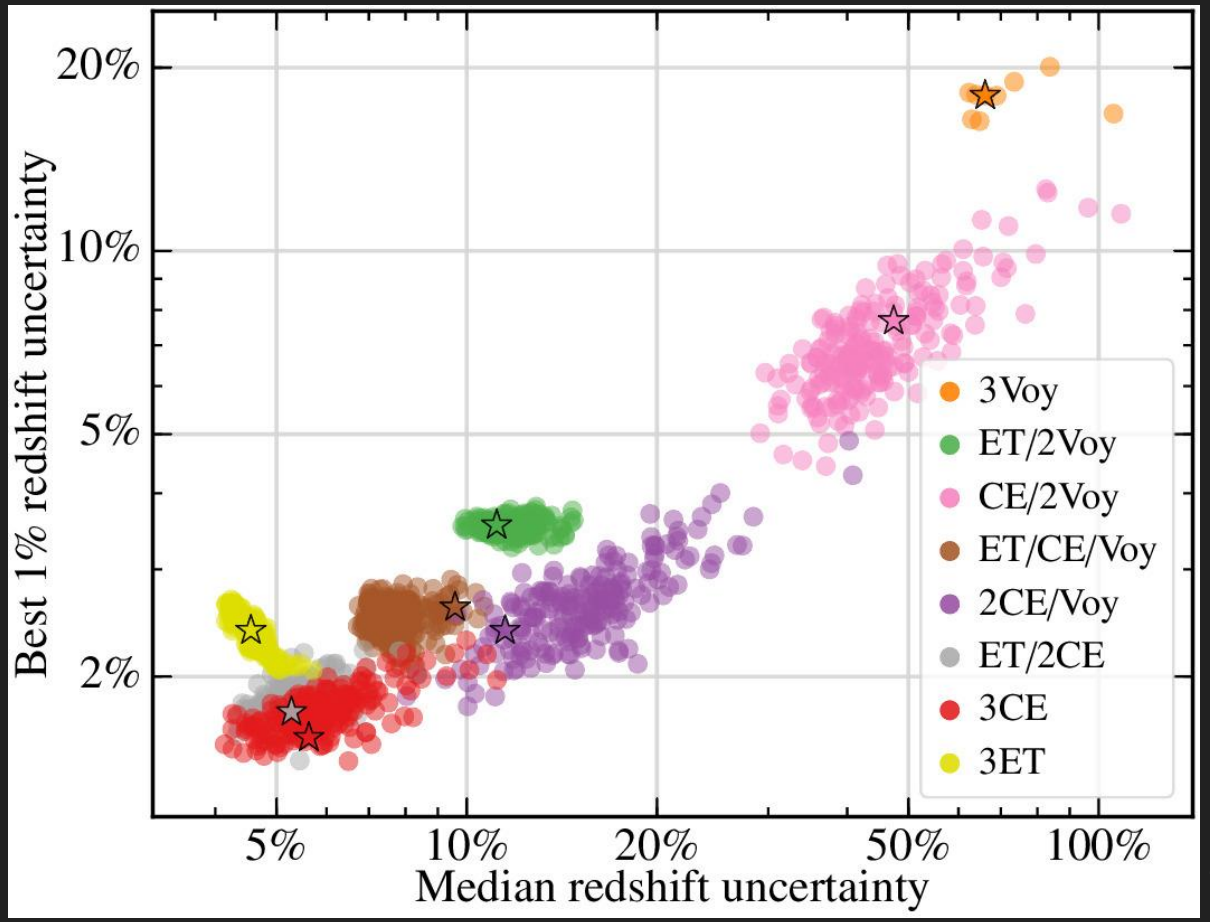
Stars: networks with plausible facility locations



Example metric: 30-30 $M_\odot$ BBH SNRs at z = 2



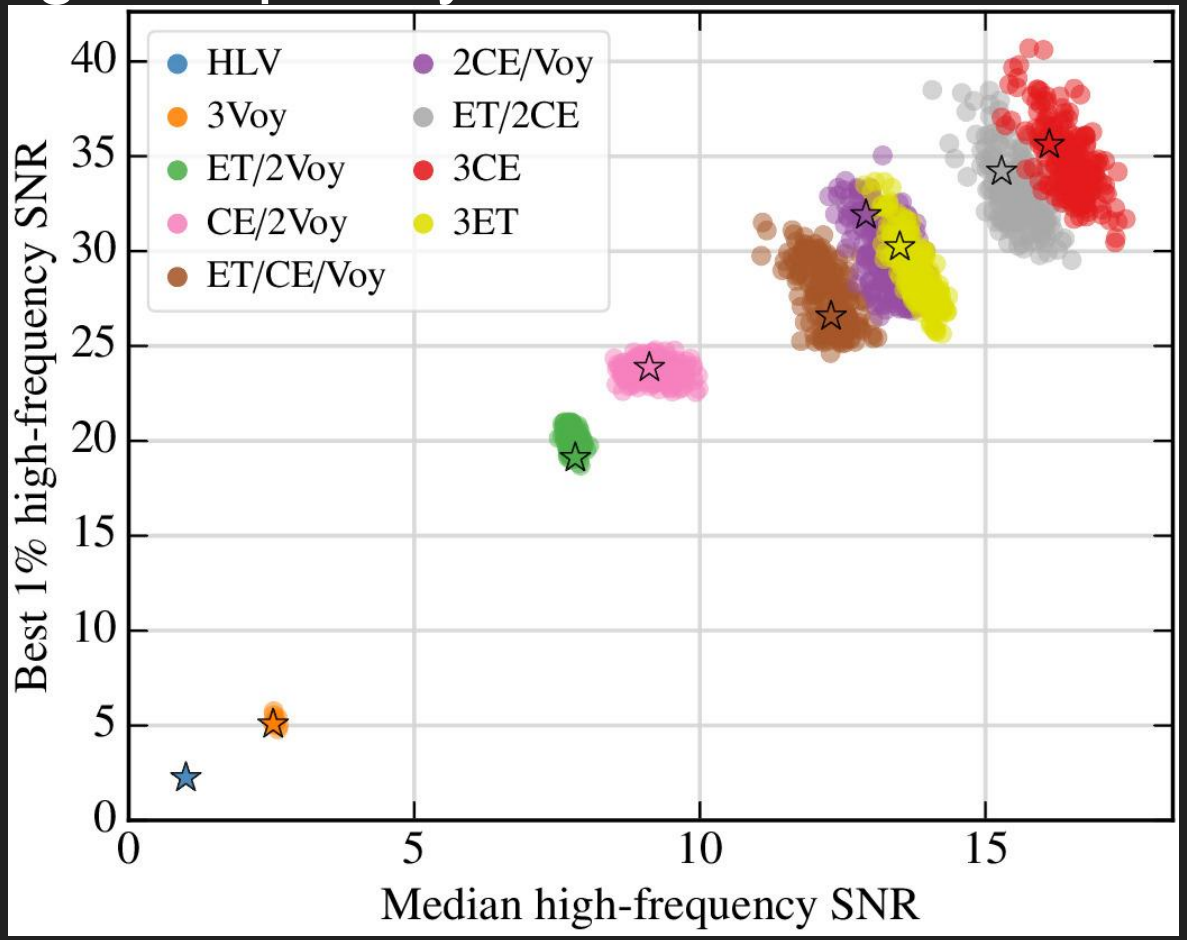
Example metric: BBH redshift uncertainty at z = 2



Example metric: high-frequency SNR

White in strain

400 Hz < f < 4 kHz



Preliminary conclusions about 3G networks

The most important factor for network performance is the kind of detectors you build, not where you build them.

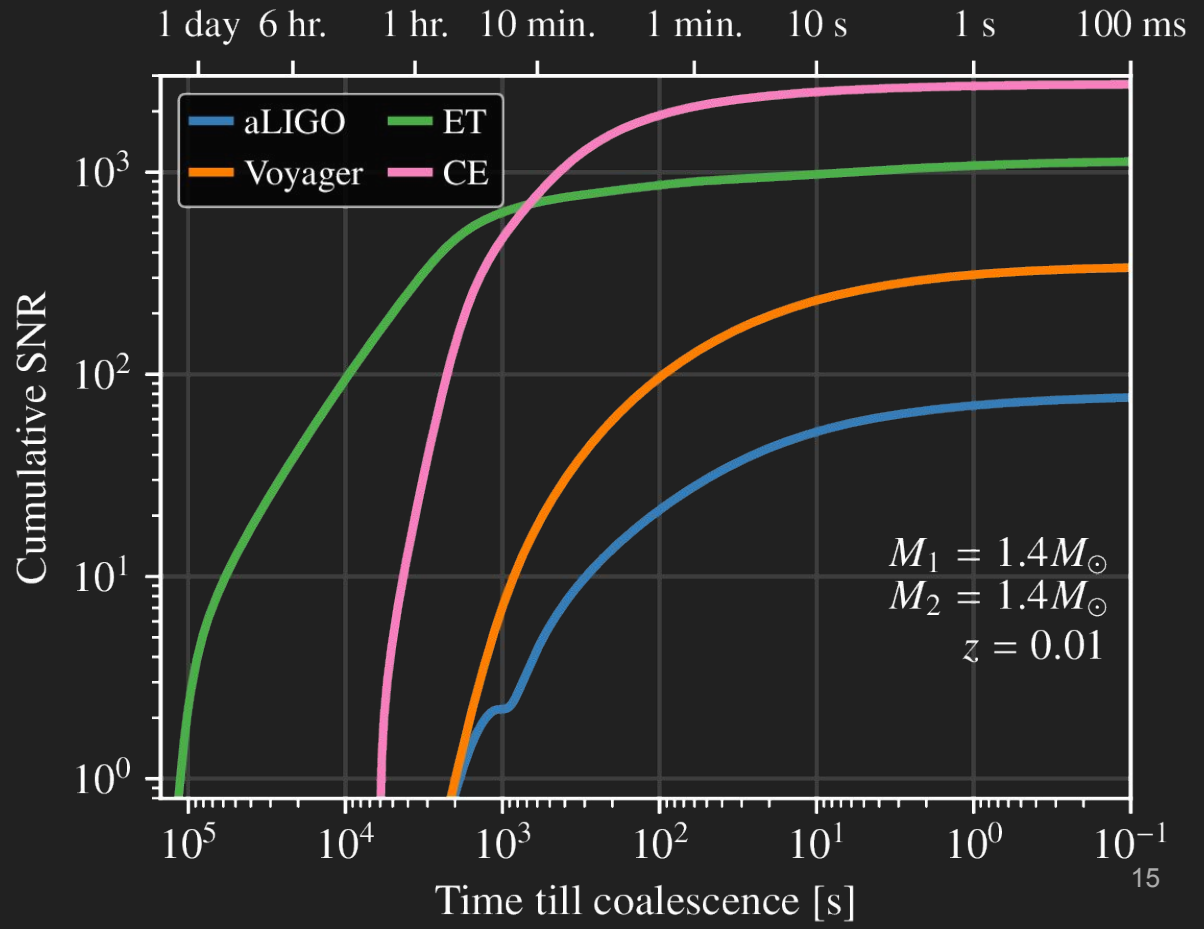
Optimizing for the average event also optimizes for the golden event, and vice versa

What about low-frequency performance?

Detect high-mass systems

Localization/PE for high-mass/high-redshift systems

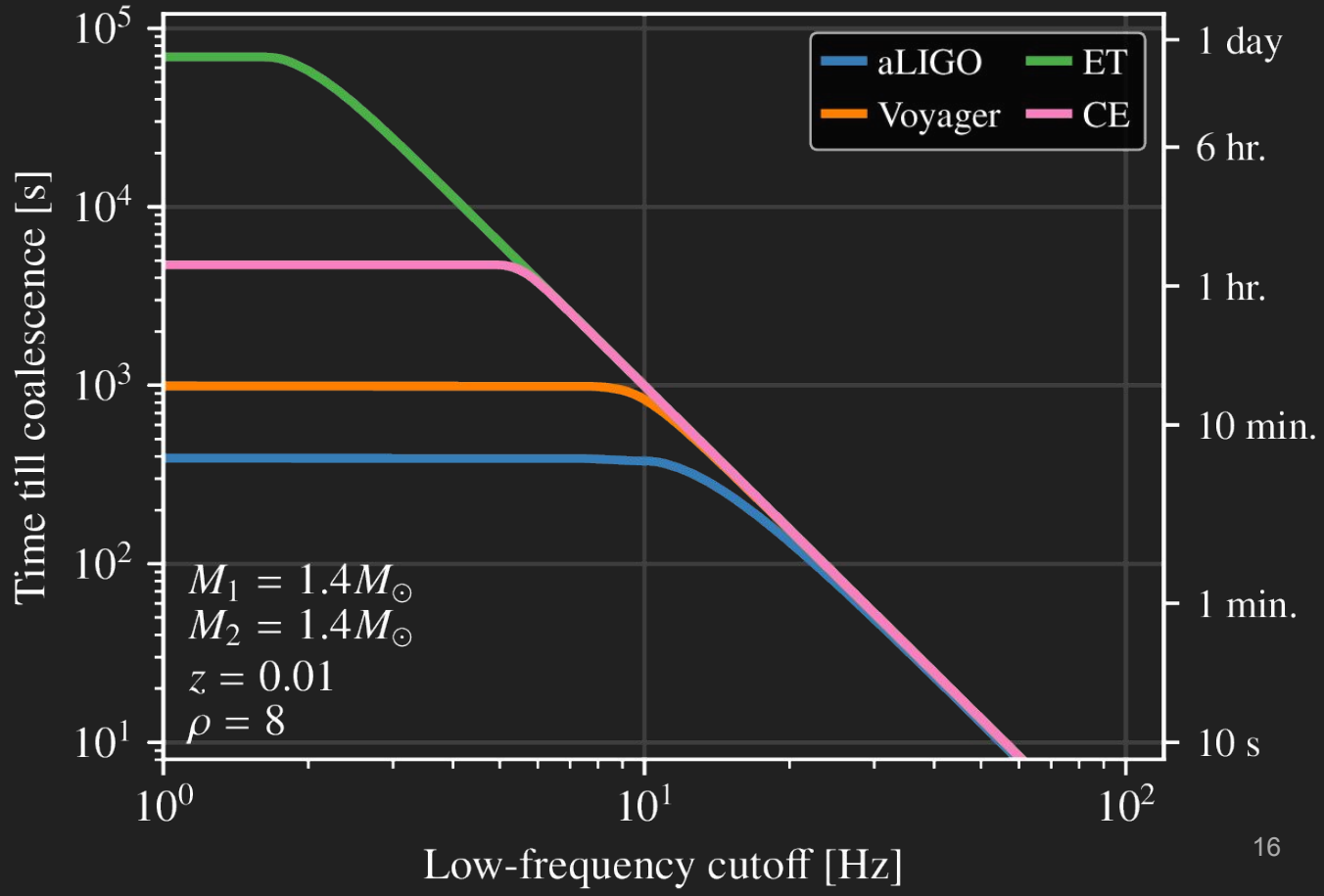
Accumulate SNR for early warning



What about low-frequency performance?

What happens if you have to give up on low frequency?

Suppose you send out an alert when SNR = 8...



Summary

The networks group is looking for (relatively) simple metrics that can be used to rank different networks

So far, the most important driver of 3-detector network performance is the composition of the network (how many CEs, how many ETs), rather than location or orientation

It doesn’t matter whether you optimize for the average events or the golden events

What we want to hear from other working groups

Which science goals require a network? Which don’t?

What metrics do you need?

How do your science goals depend on the network’s low-frequency cutoff?