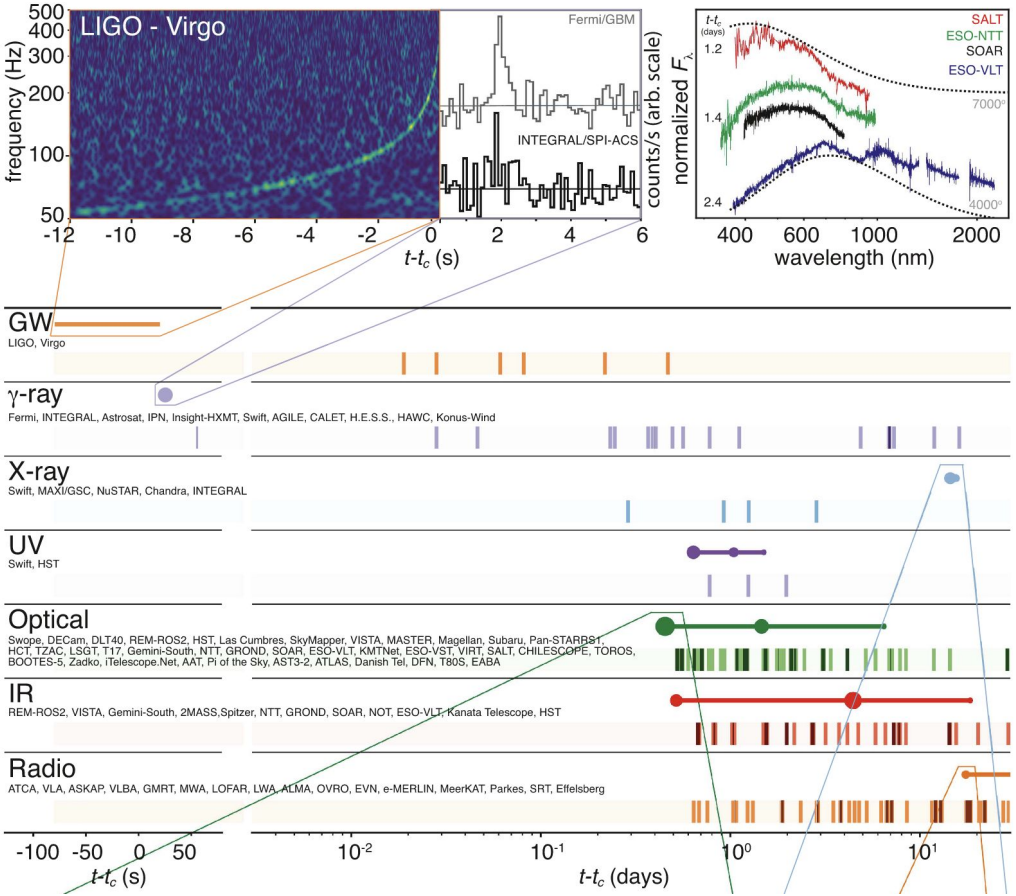
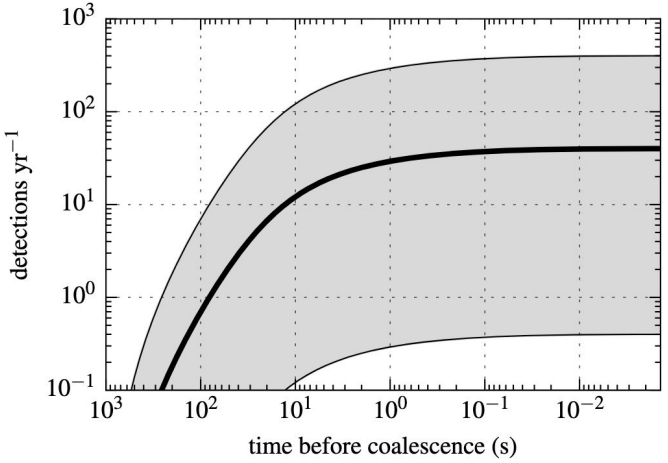
Premerger localization of compact binary mergers with third-generation observatories

Alex H. Nitz, **Tito Dal Canton**

Intro: motivation

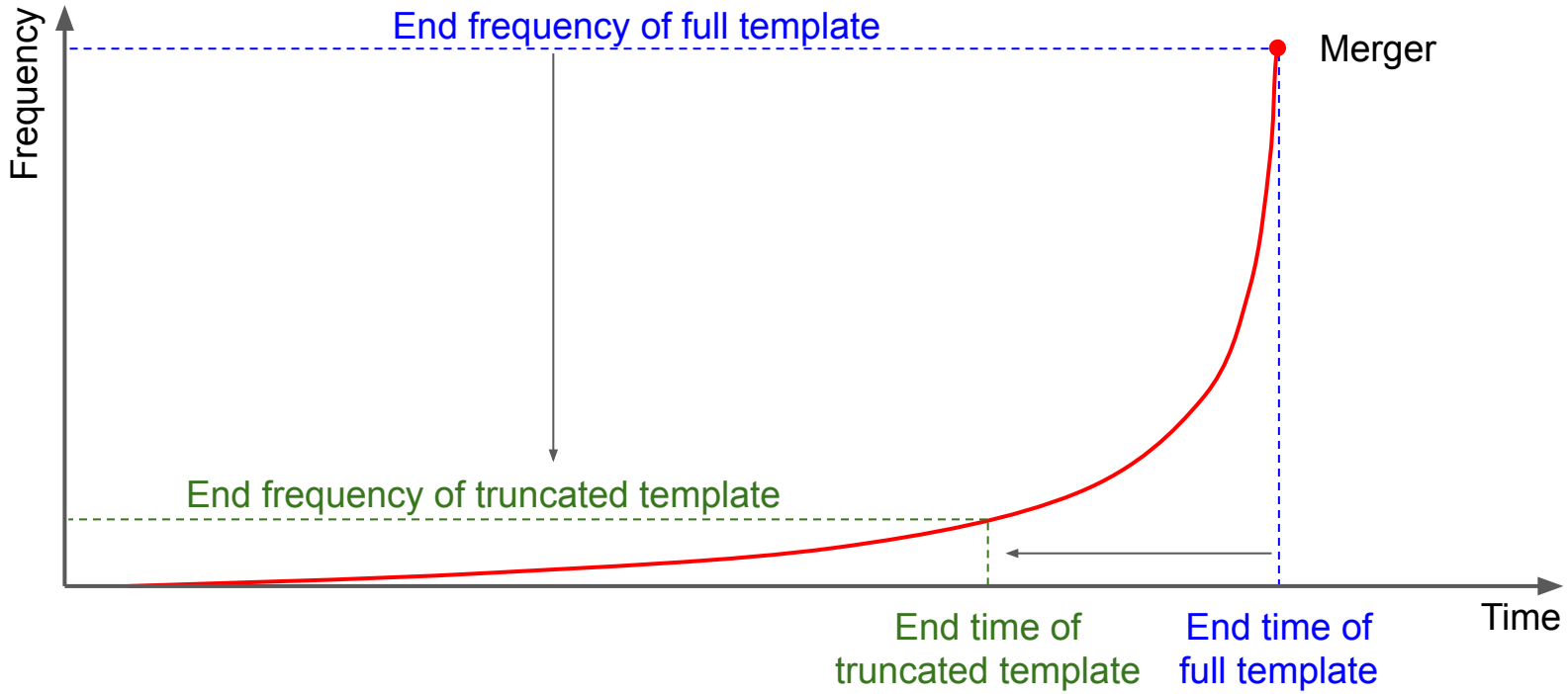




Cannon+2012

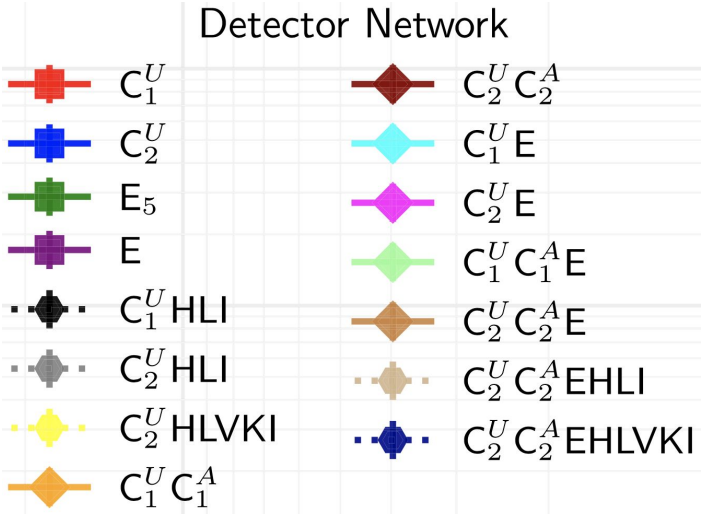
LSC + Virgo
+ many others, 2017

Intro: premerger analysis of GW data



Assumptions about the detectors

Abbreviation	Observatory	Min frequency	Noise model
H	LIGO Hanford	7	Voyager
L	LIGO Livingston	7	Voyager
I	LIGO India	7	Voyager
V	Virgo	11	O5 high
K	KAGRA	11	Design
C^U_1	CE USA	5.2	CE1
C^A_1	CE Australia	5.2	CE1
C^U_2	CE USA	5.2	CE2
C^A_2	CE Australia	5.2	CE2
E	ET	2	ET-D design
E_5	ET	5	ET-D design



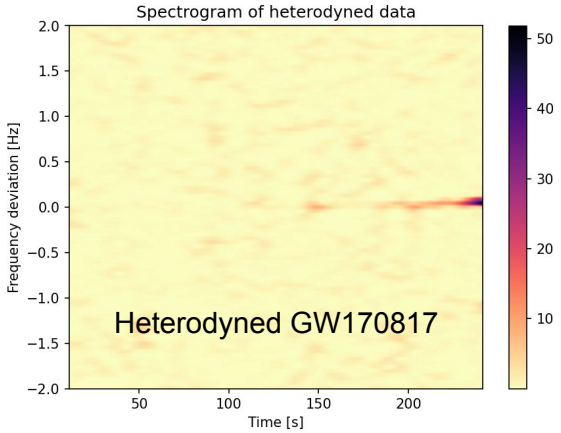
Simulated data set

- Stationary Gaussian noise
- ~10^5 BNS signals all having 1.4 M_{Sun} components*
- Fiducial merger rate of 300 $\mathrm{Gpc^{-3}\ yr^{-1}}$ at z=0 (GWTC-2 like)
- Rate evolution as in Madau & Dickinson 2014

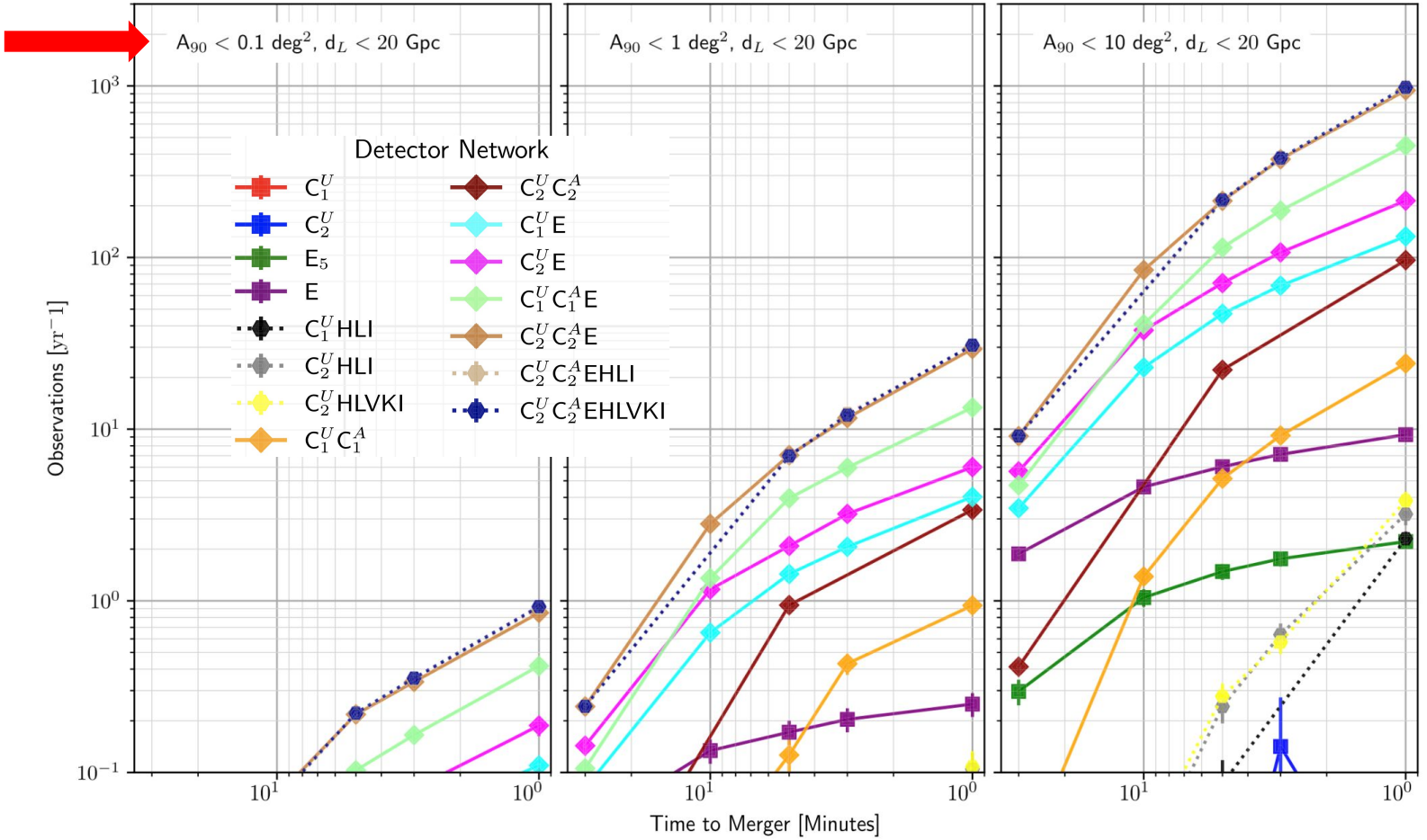
* However, a simple scaling relation is provided in the paper to extend our results to other masses.

Analysis of the simulated data

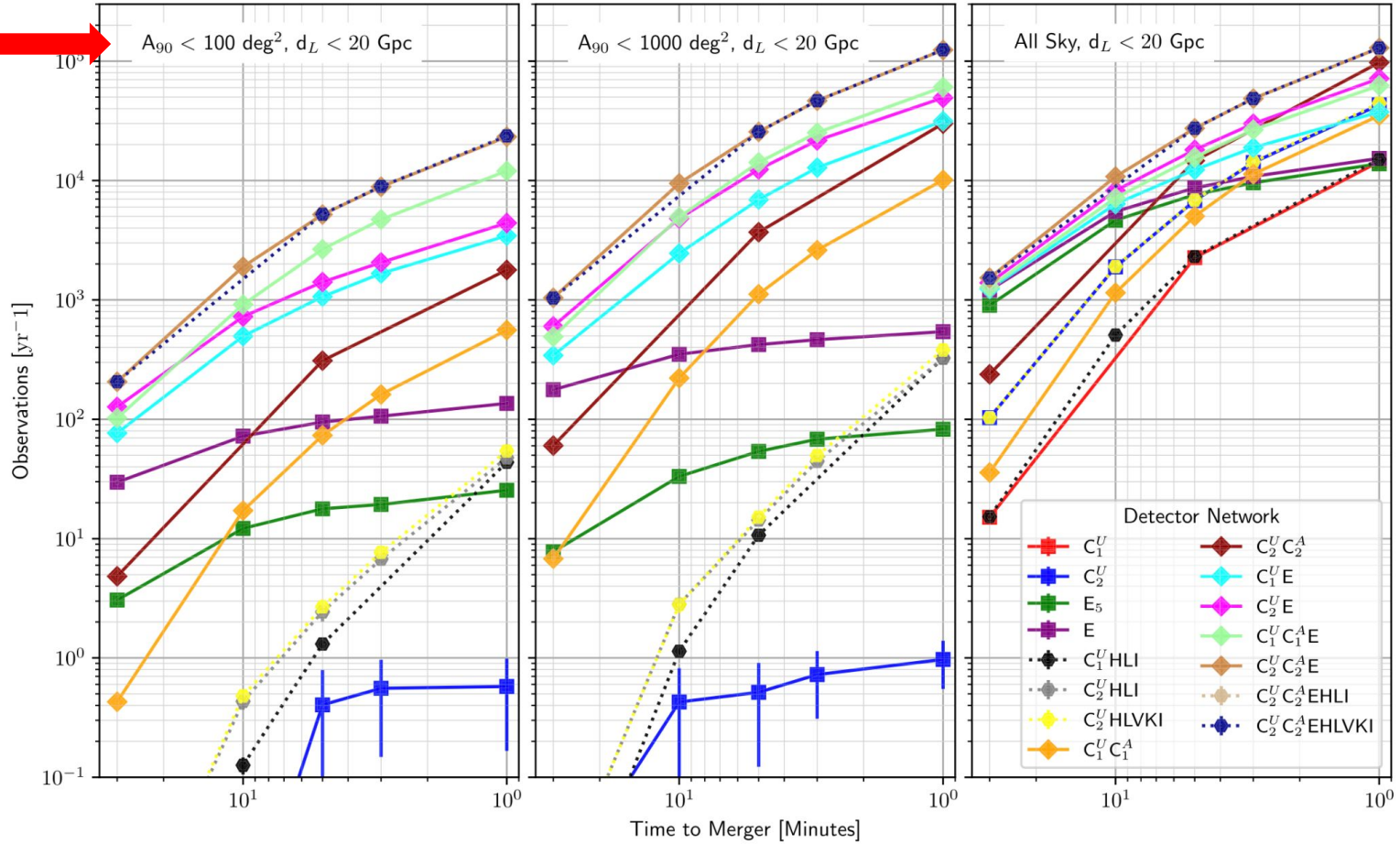
- Signal model
  - Post-Newtonian inspiral to 3.5 order (TaylorF2)
  - Non-precessing and quasicircular
  - Quadrupole order only
- Detection criterion
  - Very simple cut on network SNR > 12
  - Conservative
  - Consistent with previous studies (e.g. Nitz+2020, Magee+2021)
- Sky localization of detected signals
  - Full Bayesian inference - *not* a Fisher matrix approximation
  - Heterodyning to reduce the sampling of the signal (e.g. Cornish 2010, Finstad & Brown 2020)
  - Earth rotation taken into account
  - Nested sampling via Dynesty package
  - Isotropic priors on sky location and orientation
- Cost: hours to days on a single core for one signal



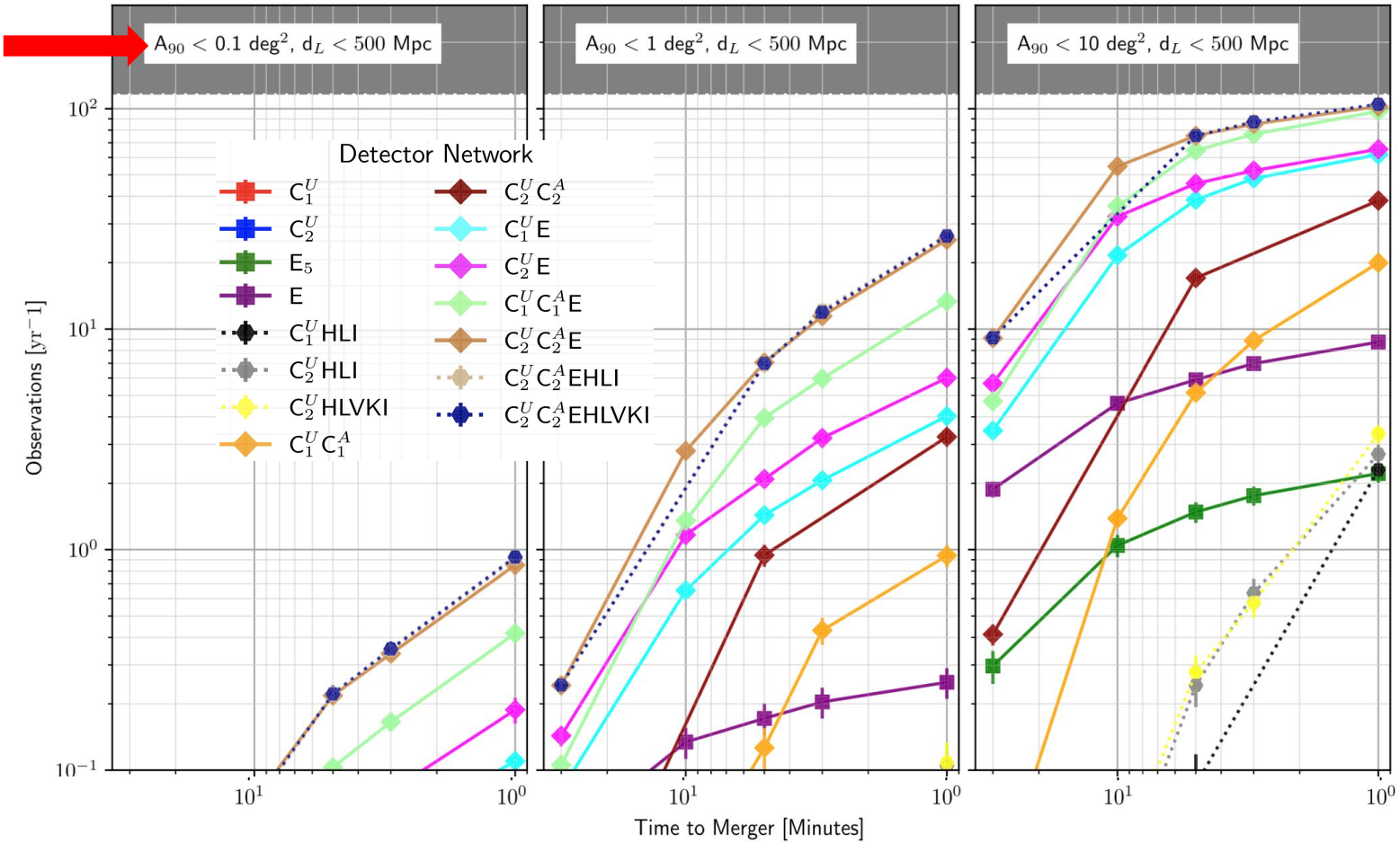
Detection rates with precise sky localizations



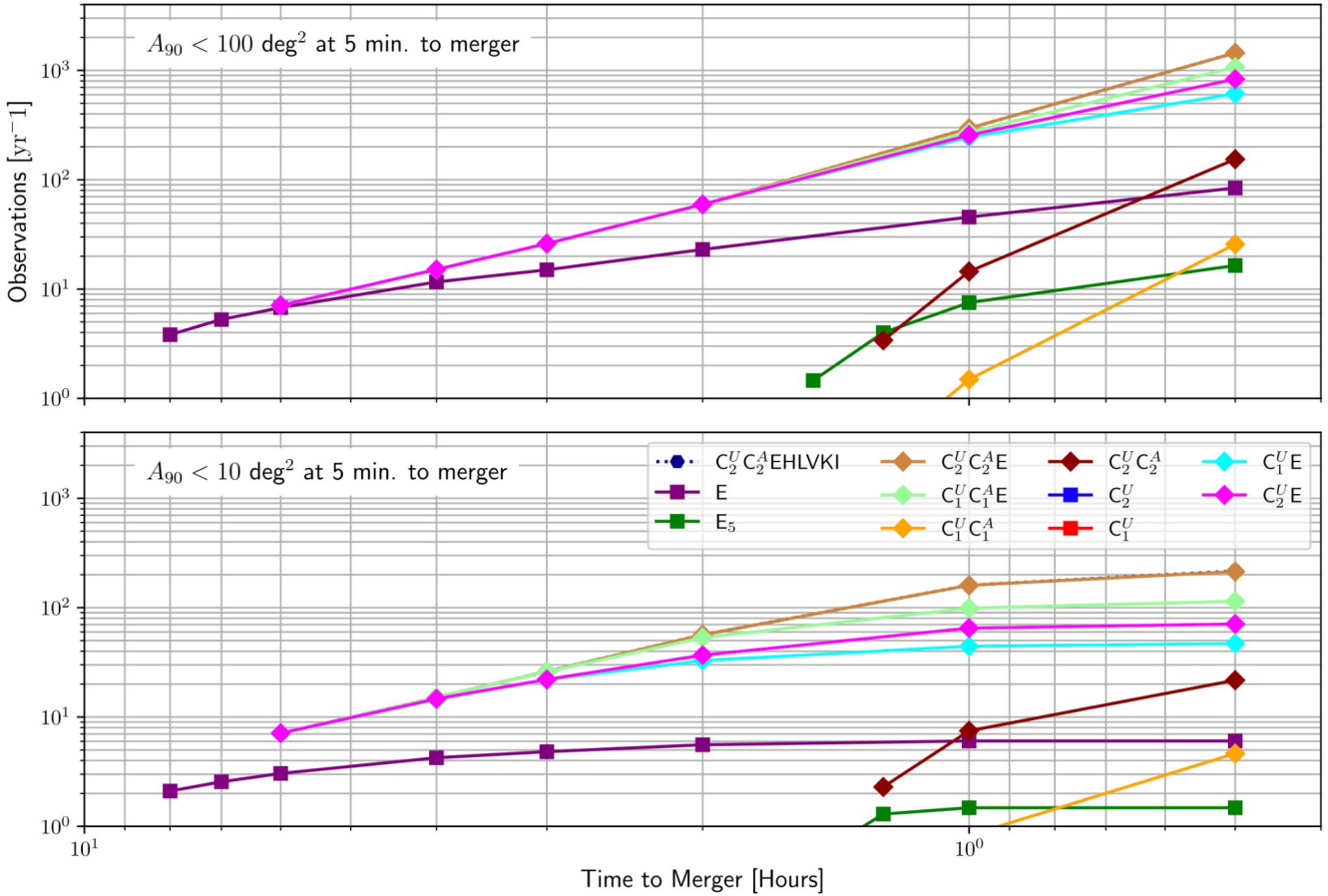
Detection rates without precise sky localizations



Detection rates: precise sky localization & nearby



Wider look at the last several hours before merger



Conclusion

- Premerger BNS detections with precise localizations minutes before merger can become commonplace in the 3G era.
- Potential for several EM observations at, or shortly before, merger.
- Development needed:
  - ~minute-long spatial localization methods that include Earth rotation (maybe only for ET)
  - Sensitive telescopes for proper joint EM observations
  - Coordination

Paper: Nitz & Dal Canton 2021, https://doi.org/10.3847/2041-8213/ac1a75

Data release: https://github.com/gwastro/gw-3g-merger-forecasting

Thank you!