Toward 3G detectors, input from SNe science

an outsider's view

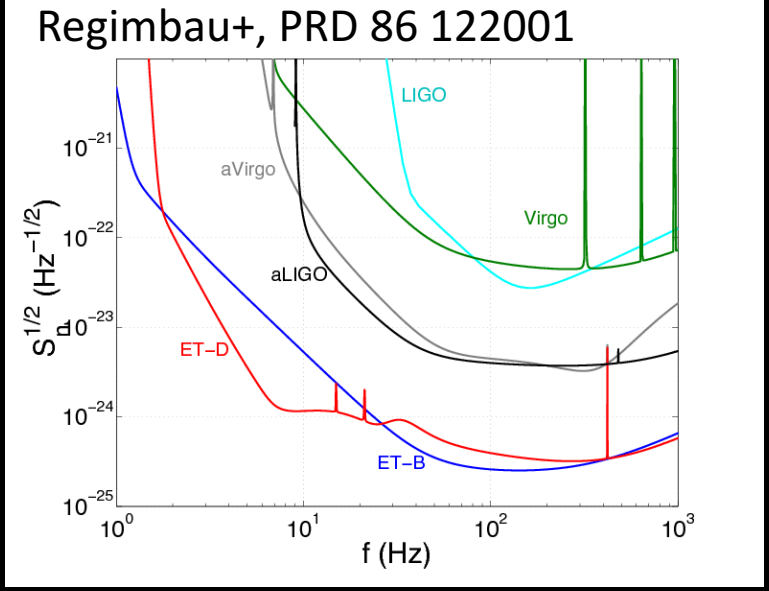
Salvatore Vitale

MIT

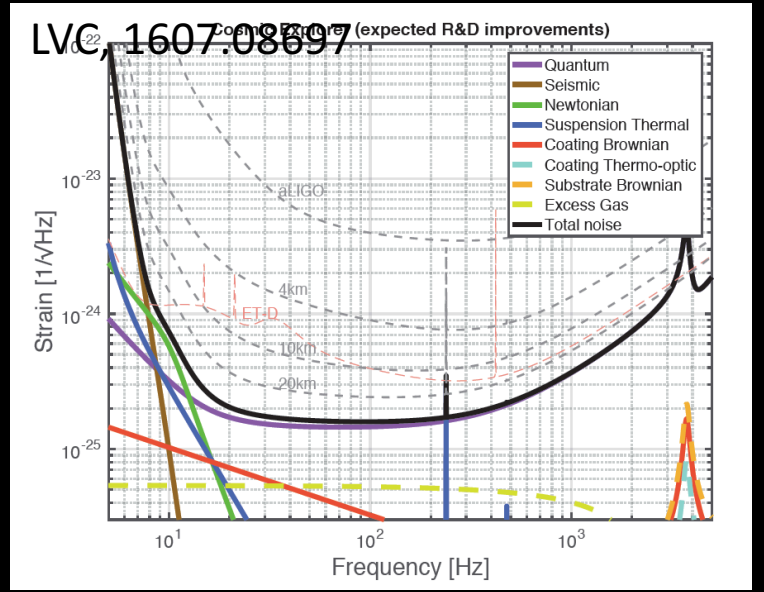
SNe-NR workshop, Caltech, March 19 2017

Proposed 3G detectors

- Einstein Telescope
  - 10 Km long arms
  - Triangular shape
  - Underground
  - Sensitivity down to few Hz



- Cosmic Explorer
  - 40 Km long arms
  - L shaped
  - Over ground
  - Sensitivity down to ~8Hz



LIGO

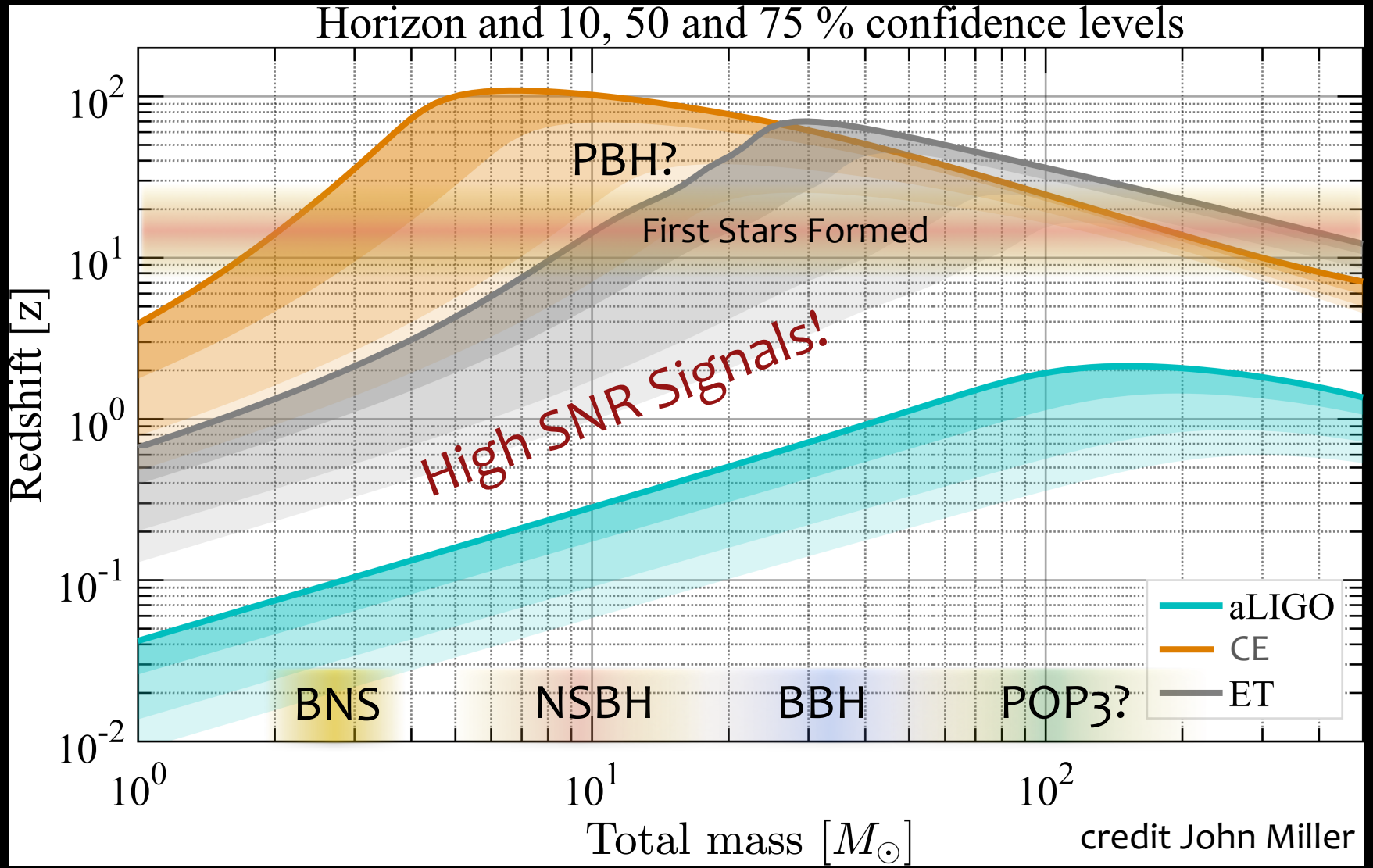
Getting to a science case

- When asking for that much money (~1 B$) there must be *good and precise* (astro)physical motivations.
- Interferometric GW detectors are delicate beasts: if you try to improve at some frequency you (typically) pay the price somewhere else
  - Trade-offs must be identified and justified (examples later)
- People *will ask* questions!

- This discussion is already quite advanced for binary black holes

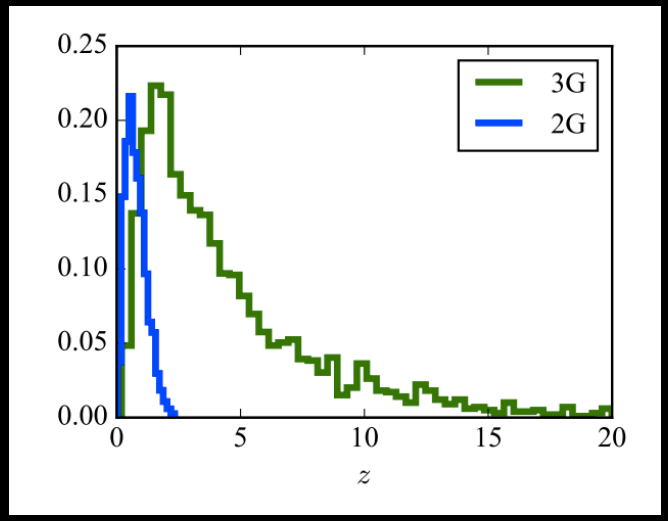
Black holes everywhere!

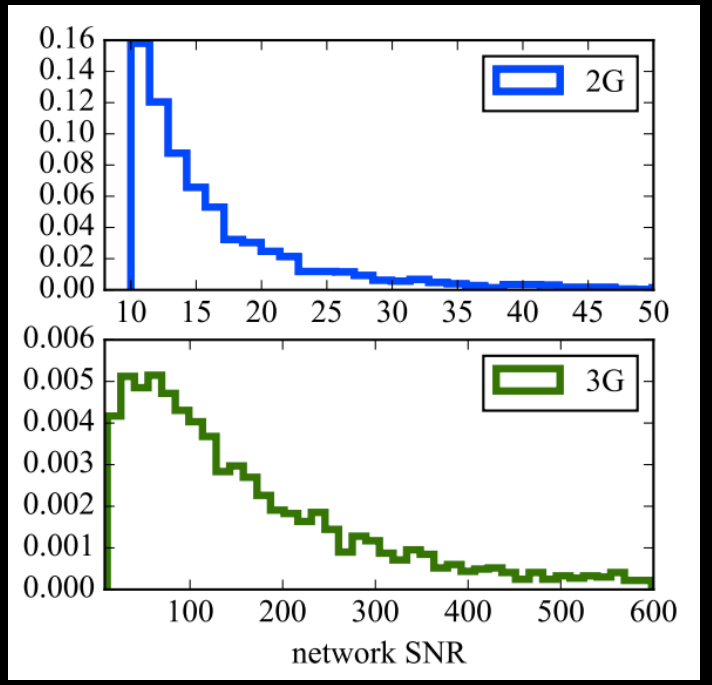
- 3G detectors can observe BBH from most of the Universe
- Many loud signals
- Cosmological distances
- How well can BBH be characterized?



Loud and clear

- BBH detected by 3G detectors will typically be loud
- Their inclination angle distribution will be isotropic
- Most events from redshift of a few





BBH with component masses in range [6,100]M

Vitale, 1610.06914, PRD Rapid Comm.

How many detectors do we need?

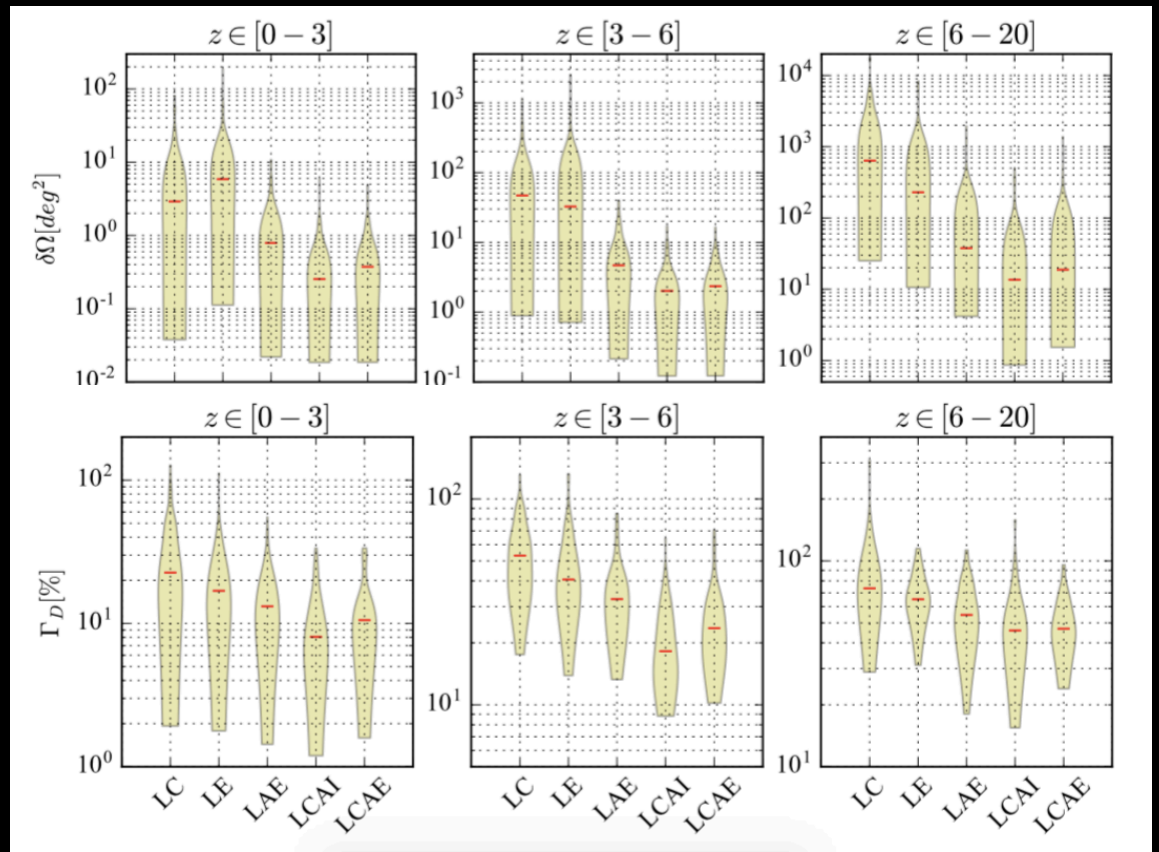
	Longitude	Latitude	Orientation	Type
L	-1.58	0.533	2.83	CE
C	1.82	0.67	1.57	CE
I	1.34	0.34	0.57	CE
E	0.182	0.76	0.34	ET
A	2.02	-0.55	0	CE

Extrinsic parameters

- With 3G detectors, distance estimation is needed to measure intrinsic masses -> need more than 2 instruments!

Sky location

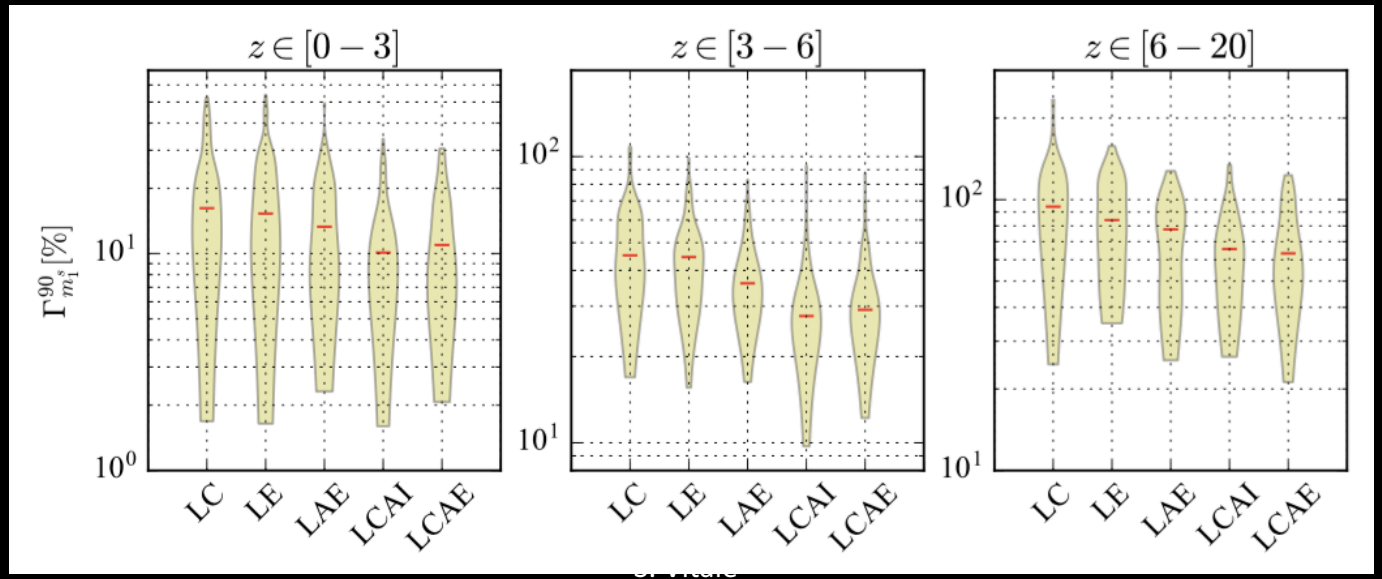
Luminosity Distance



Vitale, Evans, 1610.06917, on press PRD

Masses

- Especially at large redshifts, having more than 2 sites is important to measure component masses
- Uncertainties of [few-10]% for z<3
- Factor 1.5-2 better with 4 IFOs w.r.t. 2 IFOs

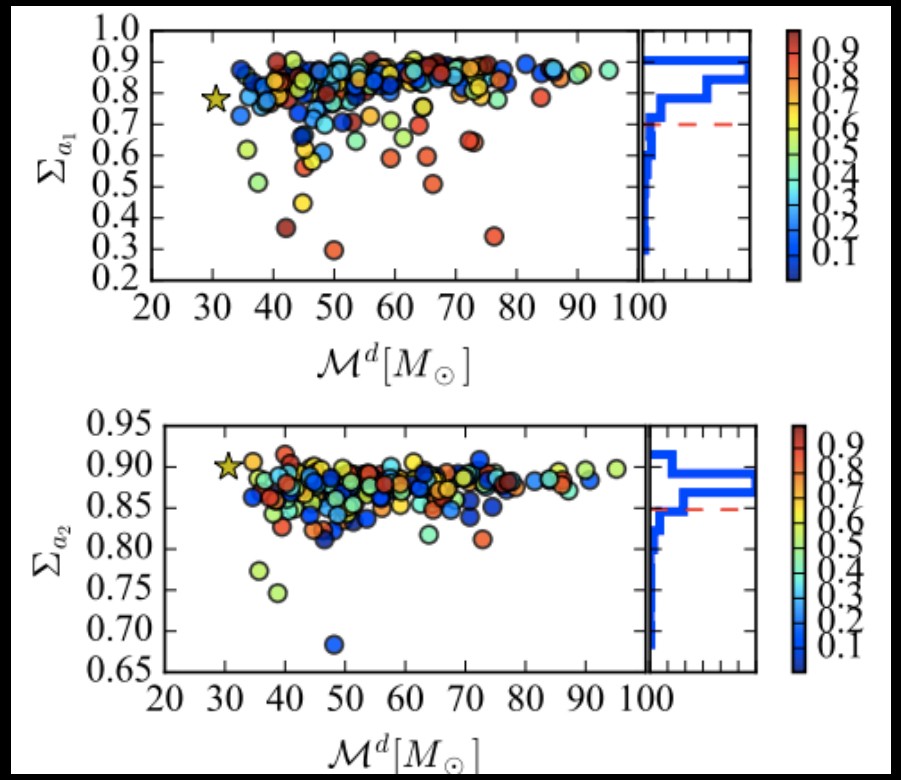


Vitale, Evans, 1610.06917, on press PRD

Spins

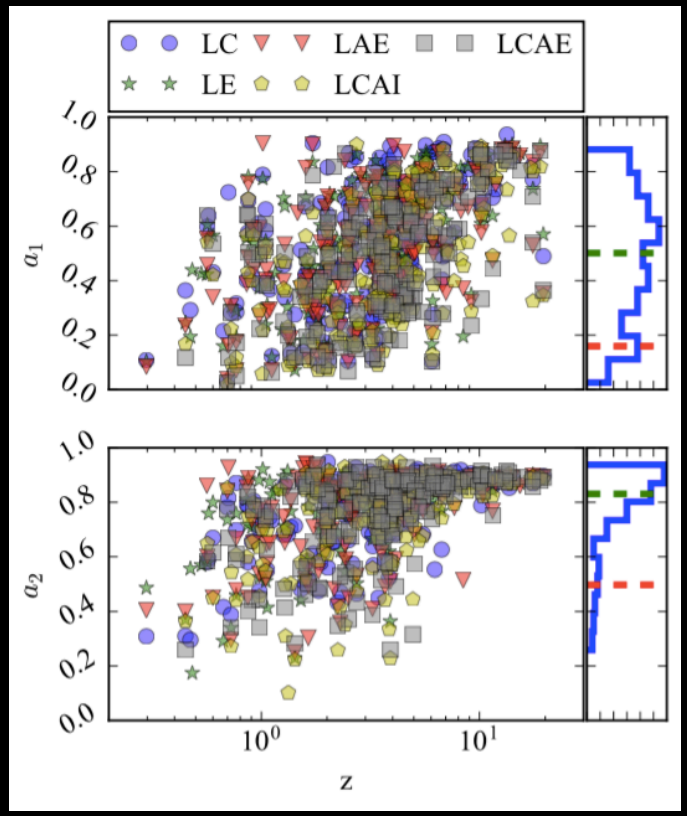
- Due to larger SNR and isotropic orbital orientation, 3G will get much better spin estimation than 2G

2G



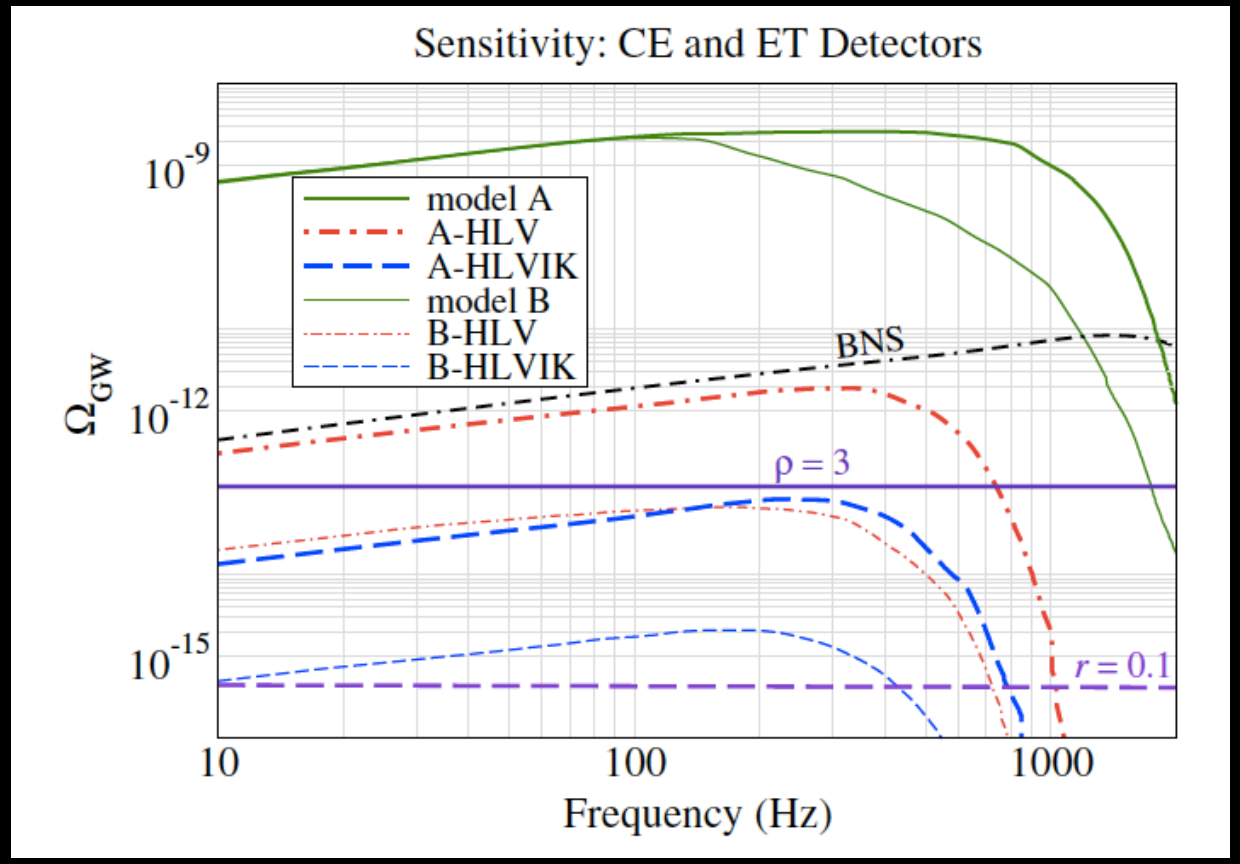
Vitale+, 1611.01122, on press PRD

3G



Vitale, Evans, 1610.06917, on press PRD

Stochastic



Regimbau+ 1611.08943, on press PRL

- The stochastic background from unresolved BBH sources will totally dominate the stochastic background form inflation.
- A significant fraction of it can be removed

LIGO

Back to SNe

- What must be done:
  - Develop and consolidate a science case with 3G detectors
- When?
  - ASAP. If SNe-driven requirements want to have any impact, they must be brought up and justified *now*

LIGO

- So, we would like to know: to go where we want to go, where do we need to go? It’s a simple information...

LIGO

- So, we would like to know: to go where we want to go, where do we need to go? It’s a simple information...
- If you want to the the mental hospital, I can bring you there.

LIGO

- So, we would like to know: to go where we want to go, where do we need to go? It's a simple information...
- If you want to the the mental hospital, I can bring you there.

To play a role in the preparation for 3G detectors, you must have *answers* (quantitative, if possible)

LIGO

Detection range

- Should have precise (in the limits of possible) numbers for
  - How far can SNe be detected at 5-sigma? (please, do not use 3-sigma, great claims require great evidence!)
  - How does this number change requiring time ”coincidence” with neutrinos?
  - How does this number change requiring time, and sky and proto-NS mass and radius inferred from neutrinos? (Giulia’s talk)

Networks and such

- SNe are rare events.
  - One might be everything we get
  - Need to be sure we have at least two detectors continuously online (I'd argue one will not be enough for a first detection)
- If a choice is possible, would you
  - Renounce to some sensitivity in exchange for more reliability (high duty cycle)?
- Can/Should we try to keep old detectors online?
  - How much worse before they are useless

Detection is not enough

- Detection itself is *not* interesting. We know SNe exist and explode.
- We must *learn something* we don't already know

LIGO

How many?

- What can we learn with 1 SNe detection at threshold?
- What can we learn with 1 *loud SNe* detection?
  - Is either of these enough to excite the broad community? (i.e. people outside of this room)
  - Is this something we can *only* do with GWs?

- What if we have a second detection?
  - Would love a progression of science vs detections

- Can you learn more if you get have more instruments? Is polarization an asset?

LIGO

Test of General relativity

- We all love GR but we would all love to see it violated
- Which GR violations can be tested with SNe?
  - Scalar-Tensor (Davide's talk), dispersion relation (Quentin's talk), extra polarizations
- Under which conditions we can *actually* test GR with SNe?
  - Are these tests competitive with what will be done in the next 20 years?
- Is one event (which might be the only thing we get) enough?

LIGO

Frequencies

- Most people commonly associate SNe to kHz frequencies
- At this workshop, the role of low-frequency has been stressed
  - What can we learn if we start the analysis from 1Hz that we would not if we started at 10Hz?
- Not a random questions: the ET vs CE designs *do* differ in the low frequency cutoff.
- Neither side is sold to a design yet. If going to 1Hz would make SNe science dramatically better, *we need to know (asap)*