GW network during the SVOM era

Nicolas Leroy
LAL IN2P3/CNRS - UPSud

GW network mid 2020

O3

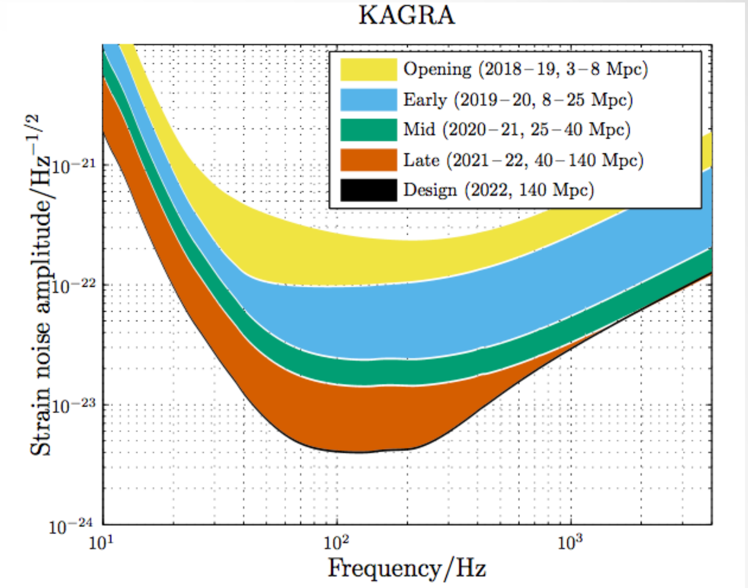
- Will start not before end 2018, more probably beginning 2019
- Will last for one year
- Planned range (averaged distance on all angles for detection above SNR=8)
  - LIGO : 120 Mpc
  - Virgo : 60-85 Mpc
- KAGRA (Japanese detector) may join at the end of the period if its range is above 20 Mpc
- GW network is moving towards open public alert
- Possibly up to several alerts / week

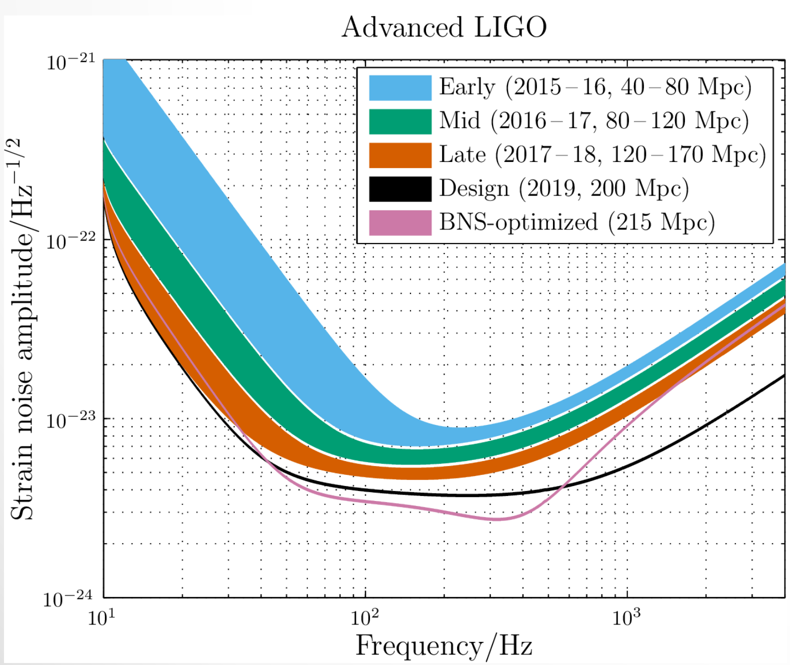
Open public alert

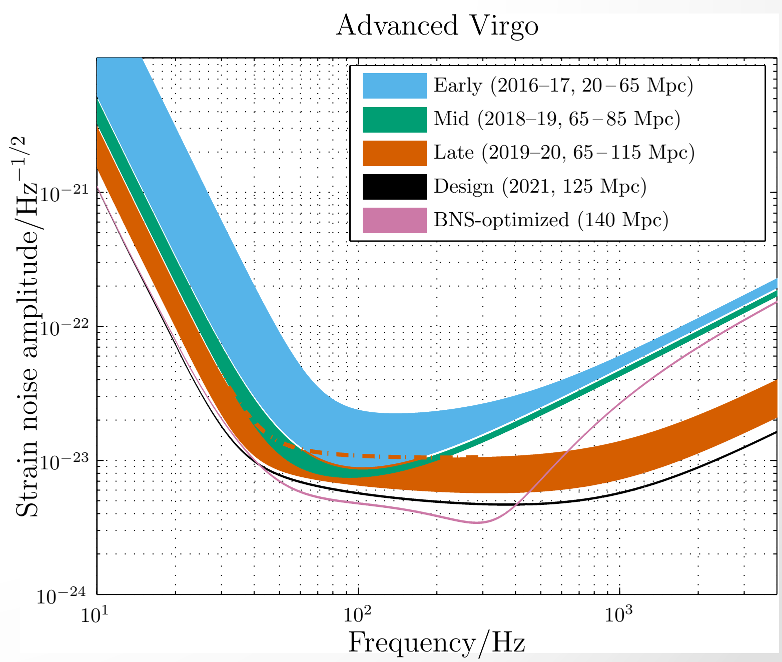
- Notices + circulars: Preliminary, Initial, Update
- 2 types of pipelines to provide these alerts:
  - Coalescing compact objects : from BNS to BBH
    - Overall astrophysical purity of 90 % - FAR : 1/month - 1 year
    - Will provide skymaps with 3D information
    - Probability to have a NS in the system
    - Probability to have EM emission (based on Pannarale & Ohme (2014))
  - Unmodelled transient source:
    - Use more restrictive cut – FAR 1/100 years
    - Only 2D information
    - Could detect BBH up to 500 M
  - Will also include data quality statement

Sensitivity evolution

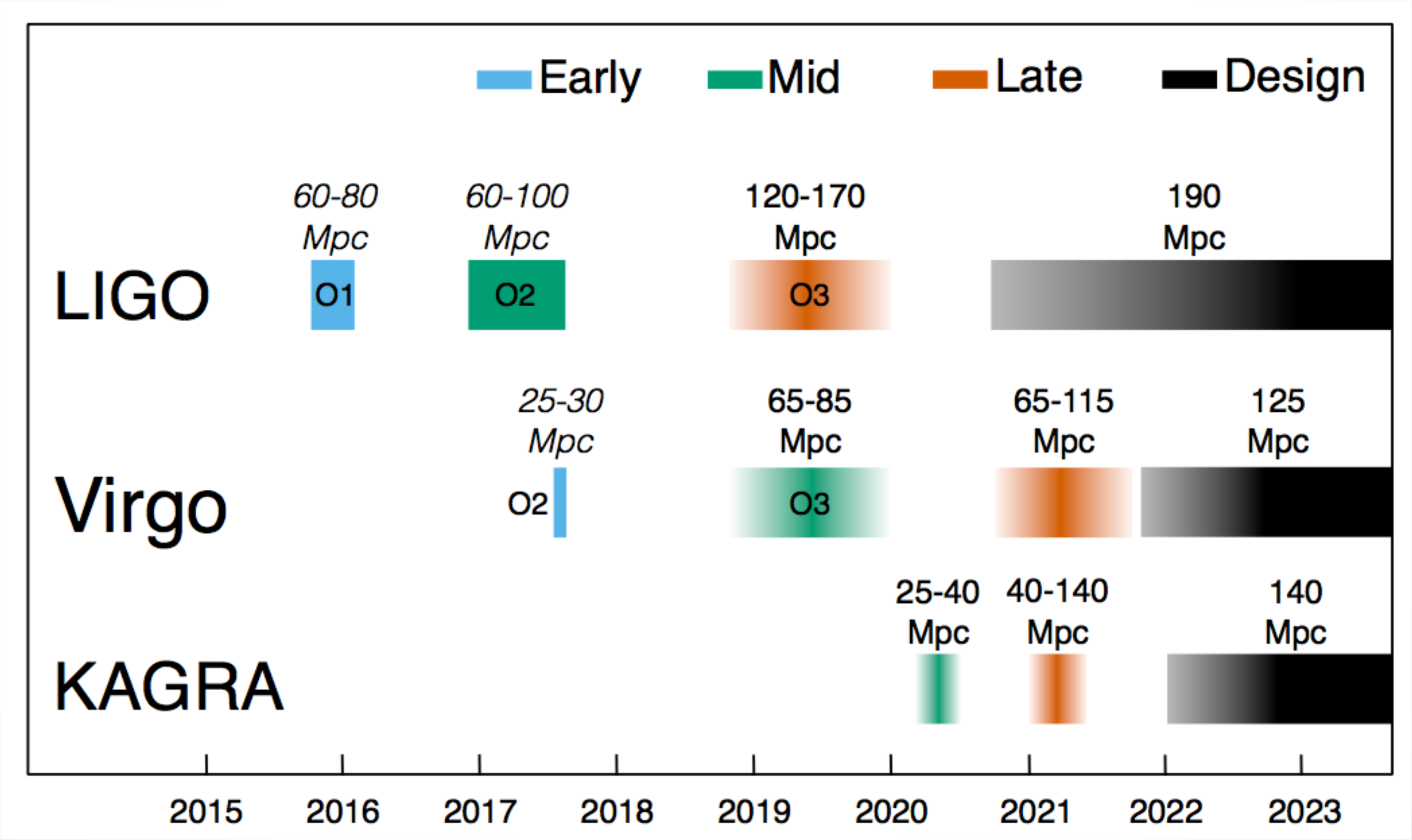
- Continue sequences of data taking and upgrades
- Reach design sensitivity
- Allow a larger volume observation







Timeline after O3

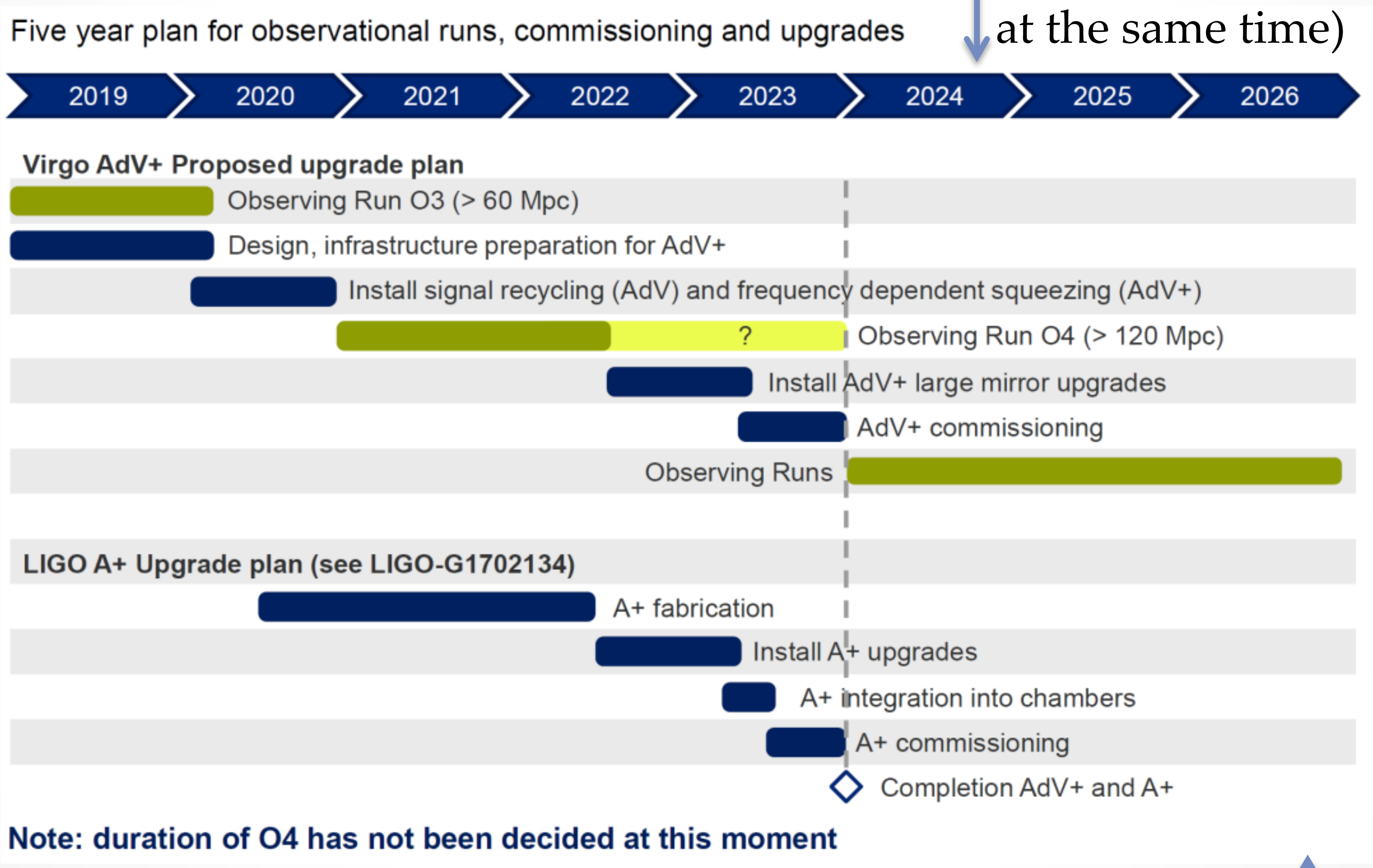


Moving to next generation

- **2.5 G:** a set of upgrades capable of enhancing the sensitivities of the current detectors (event rate 5-10x)
  - A+ at LIGO, AdV+ at Virgo - Timeline:~2023
- **2.75G ? :** use the current infrastructure to its maximum and prepare 3 G
- **3 G:** new infrastructures/detectors capable of reaching the early universe. One order of magnitude gained in sensitivity wrt 2G
  - Timeline: ~2030 - Cost > 1 Geuros
  - Einstein Telescope: European project for a nested assembly of 6 co-located interferometers, 10 km long underground
  - Cosmic Explorer: US project for a 40 km interferometer surface detector

Post O3 program

LIGO India (same as LIGO at the same time)

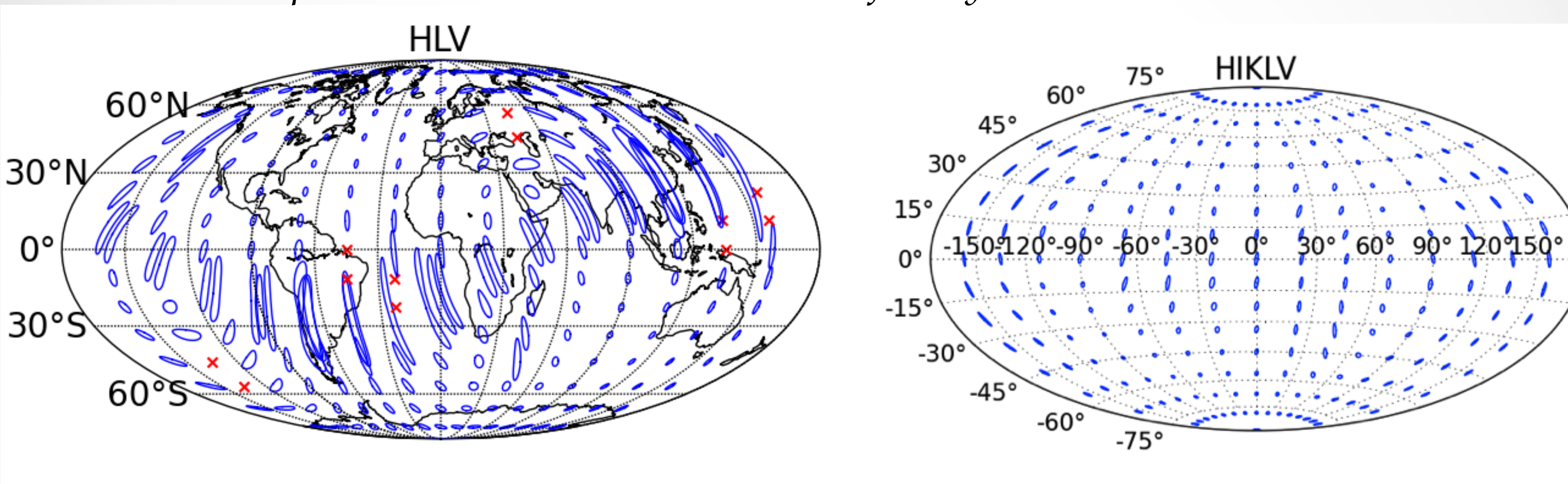


KAGRA

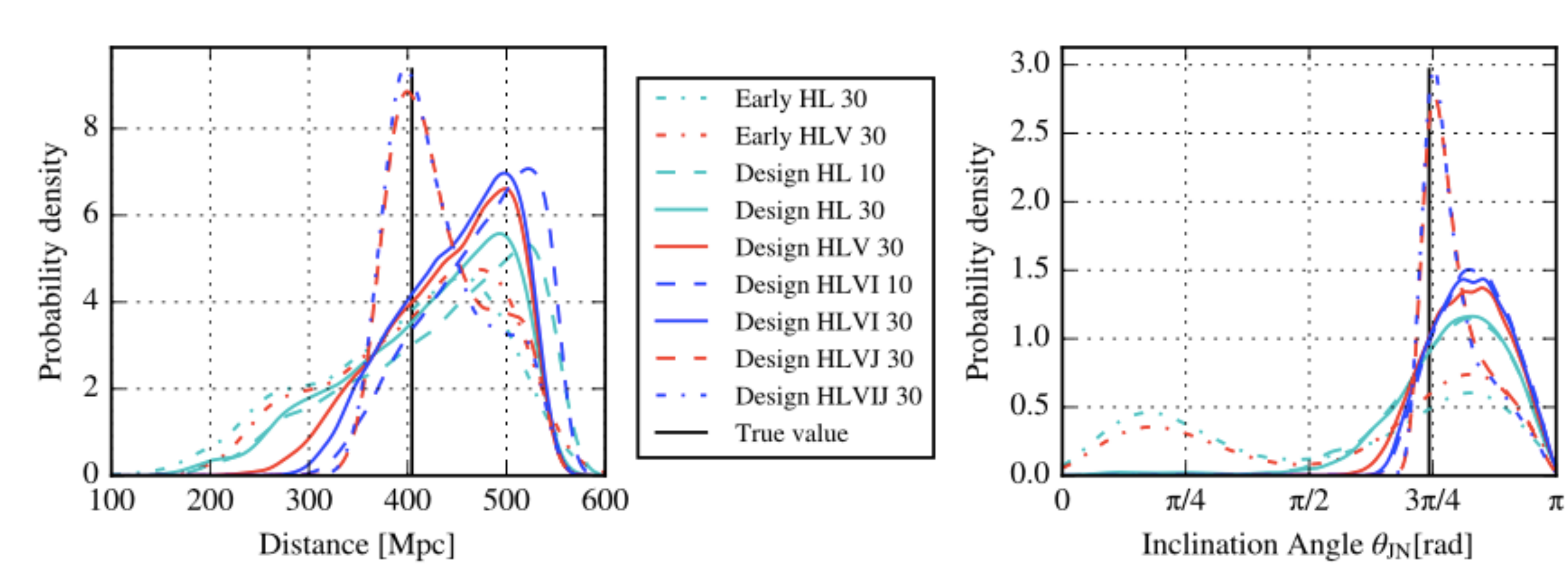
LIGO Voyager ?

Parameters inference

Comparison between 3 and 5 detectors for sky localization

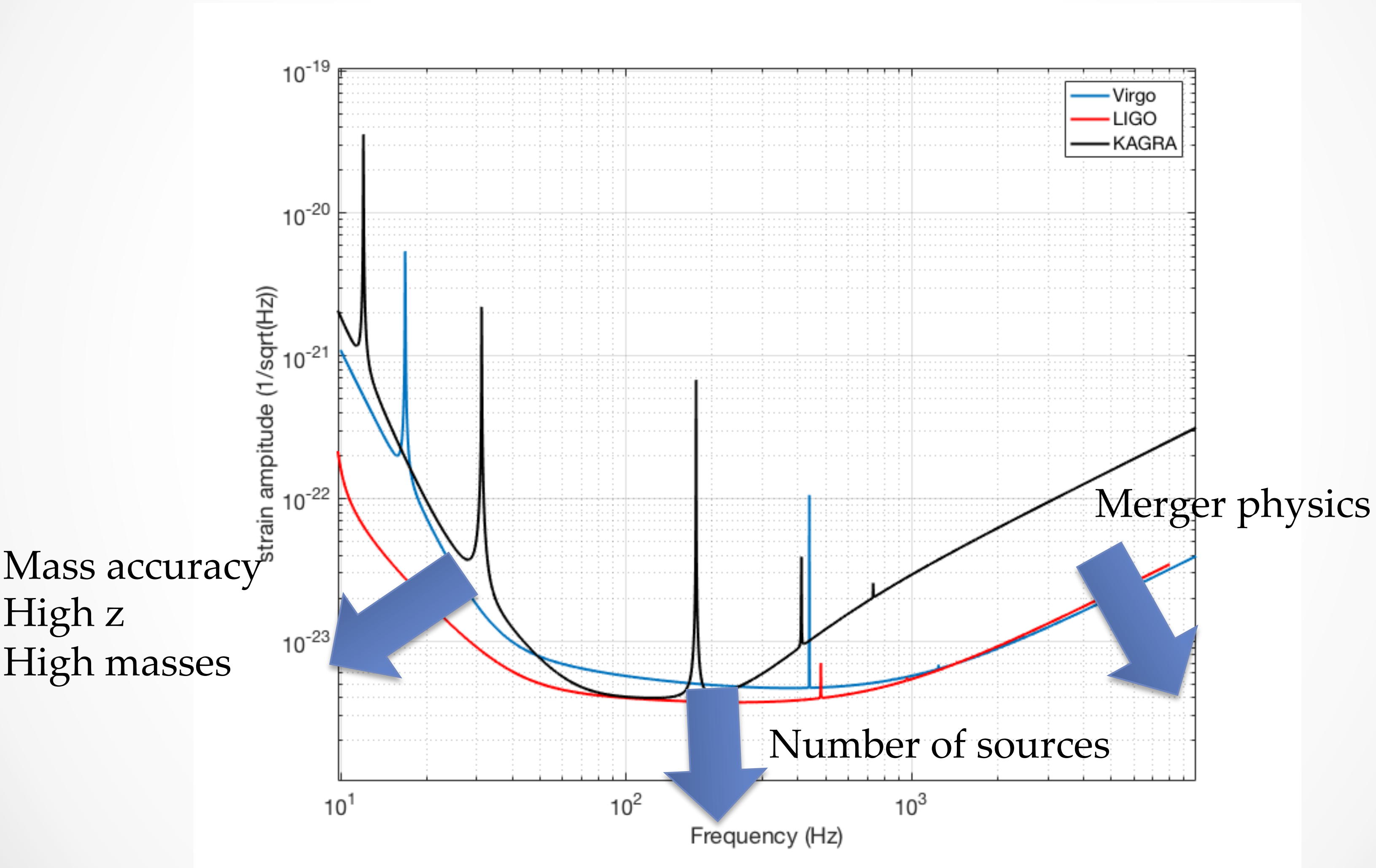


Fairhurst, proceedings of ICGC2011 conference

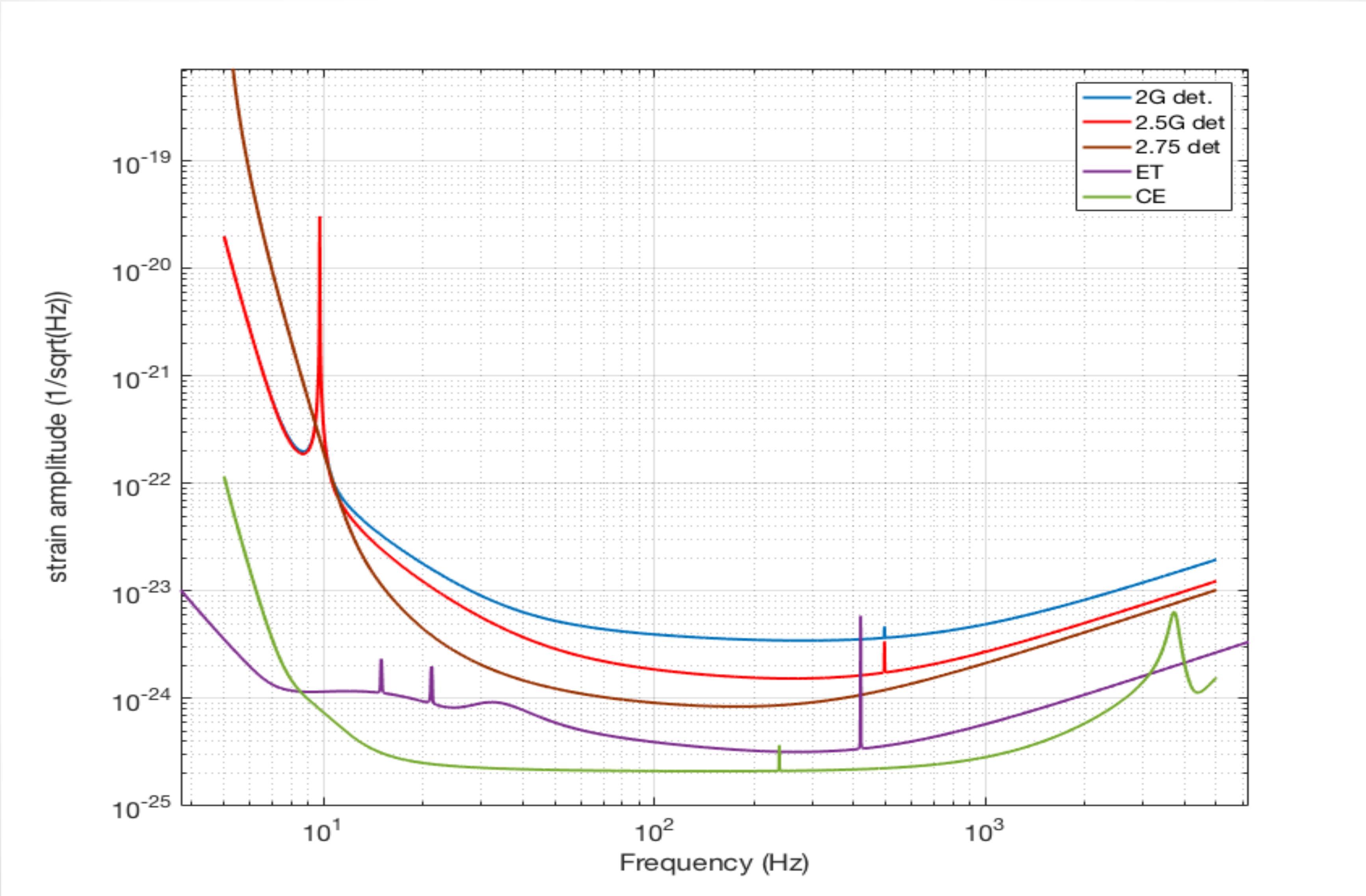


S M Gaebel and J Veitch 2017 Class. Quantum Grav. 34 174003

Improving sensitivity

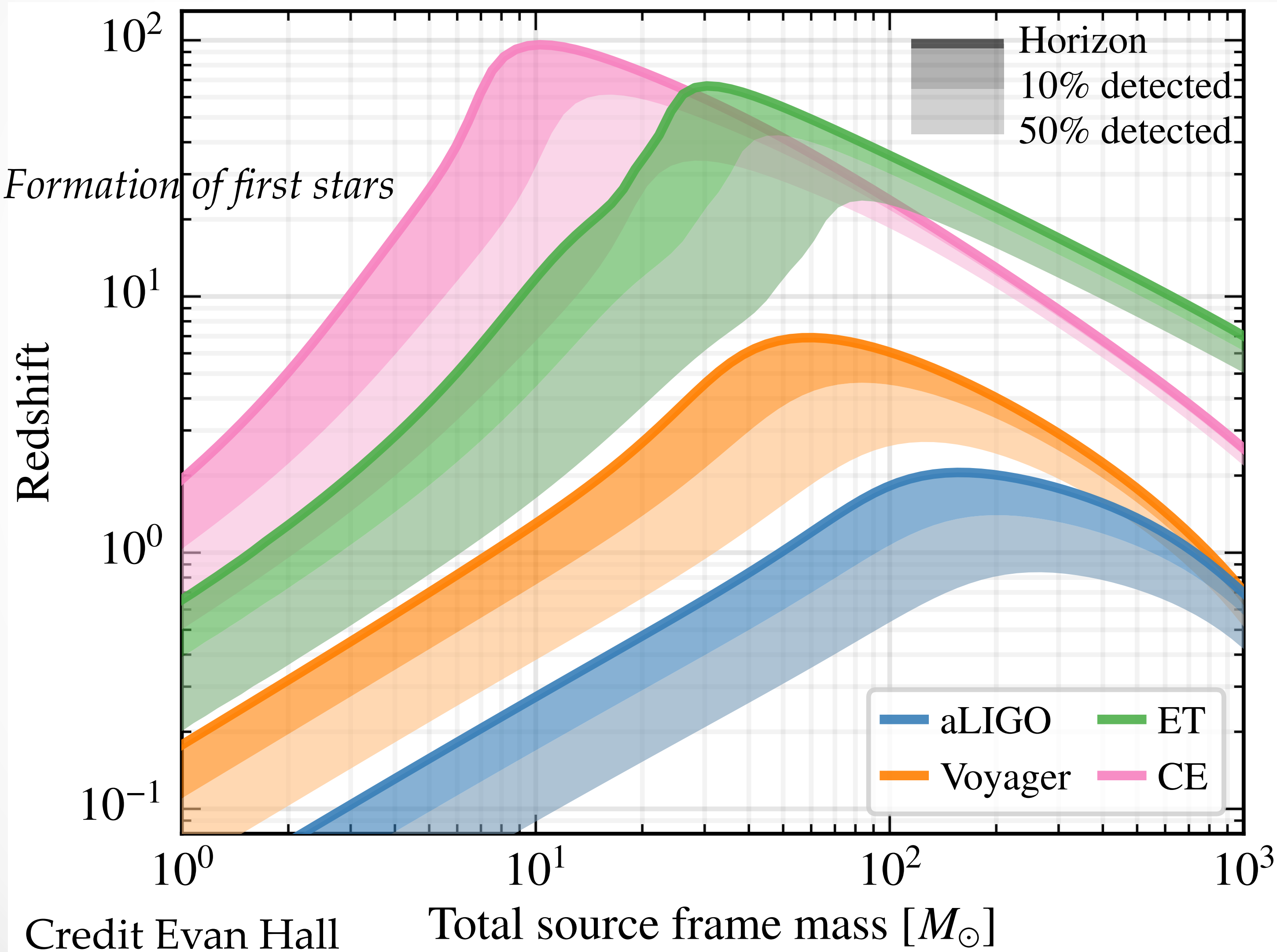


Possible scenario



Scanning a large fraction of Universe

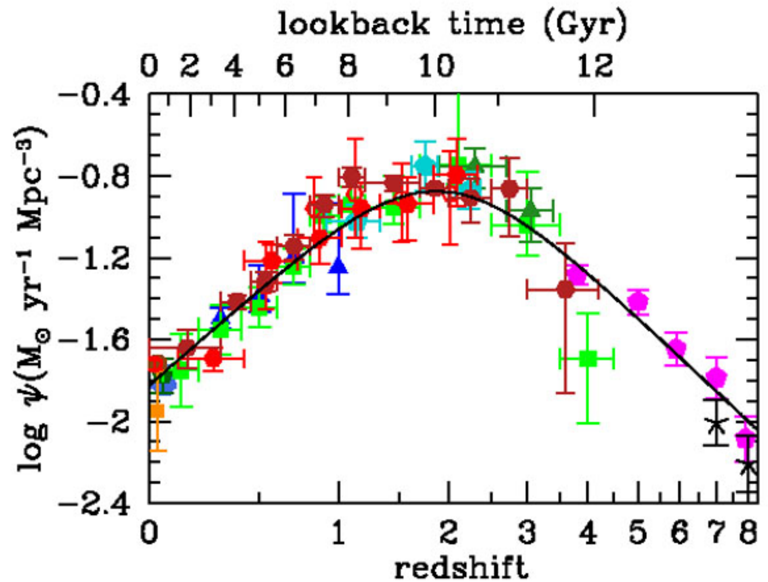
Maximal distance for coalescing objects



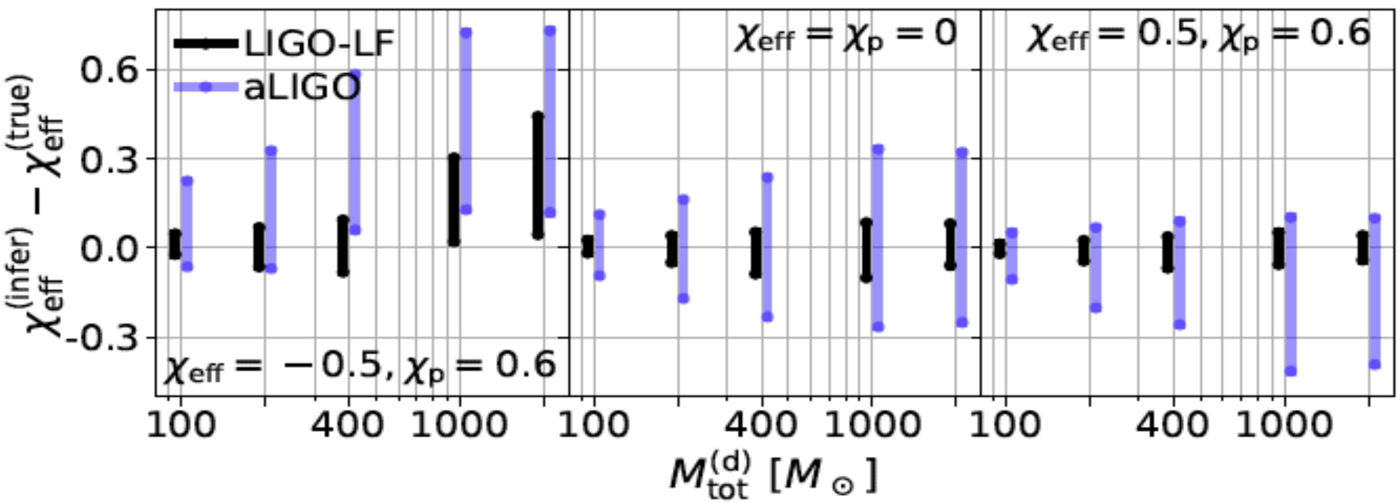
Credit Evan Hall

Coalescing history

- Better inference of parameters
- Evolution of mass and spins of the objects with distance
- When first binary black holes are formed
- Link between black holes seed and growth of cosmic structure



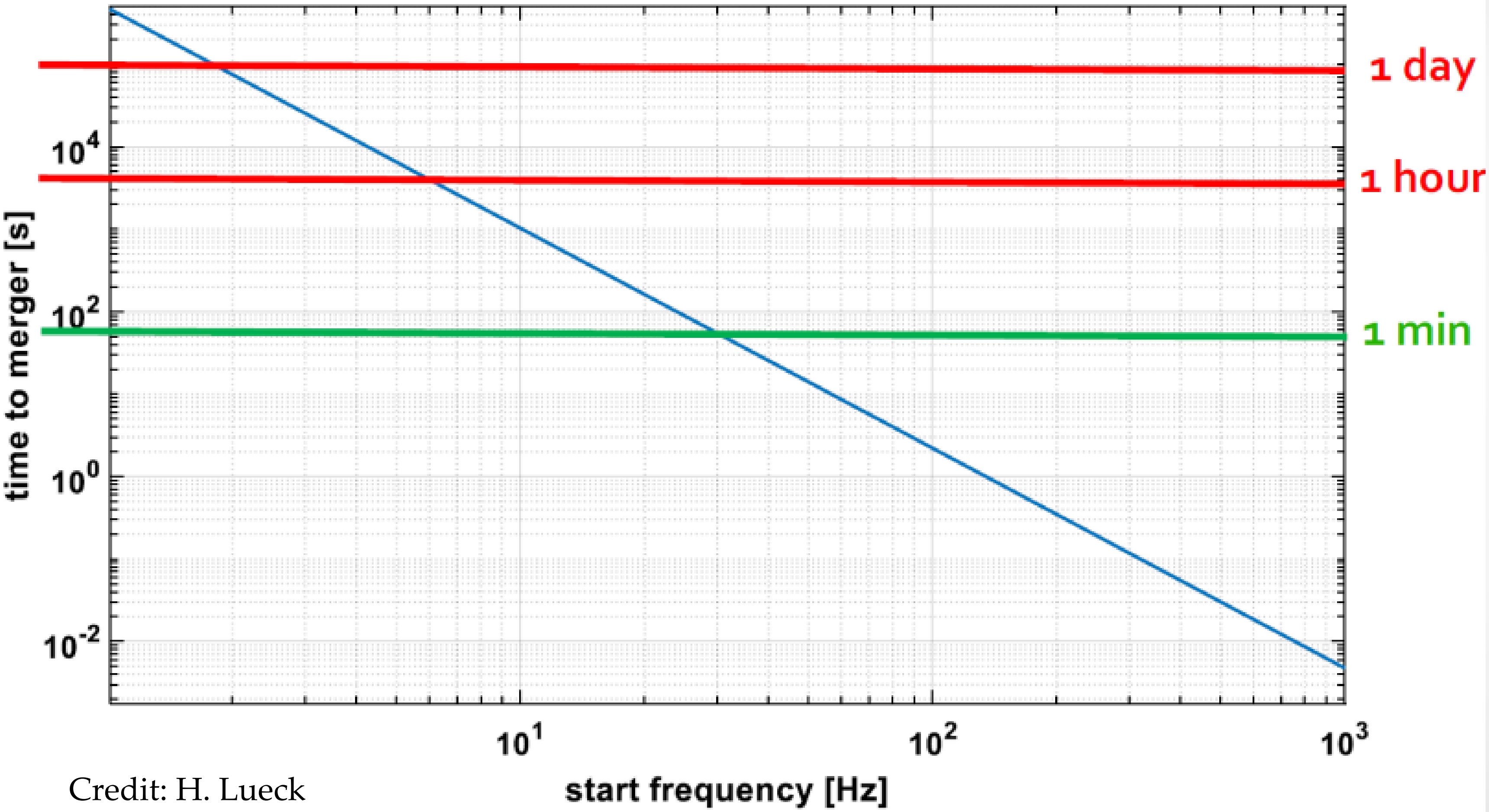
Madeau & Dickson 2014, ARAA, vol 52



Yu et al, 2018
PRL120, 141102

Early warning for EM search

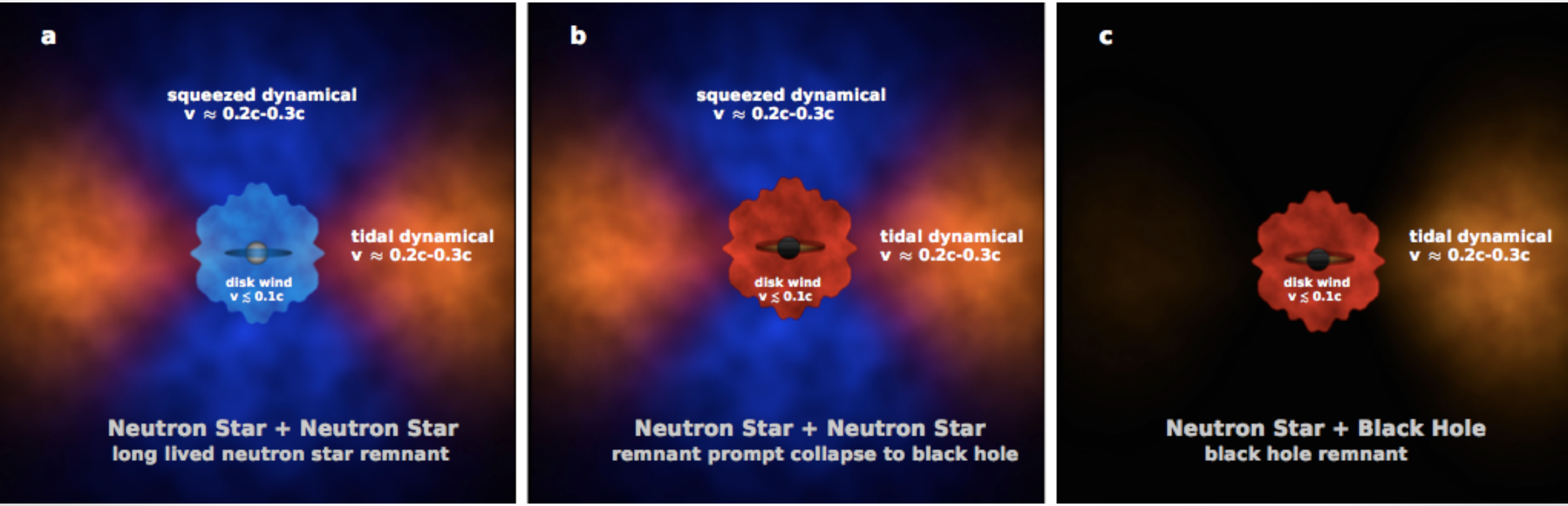
Time inside the frequency band for a BNS



Credit: H. Lueck

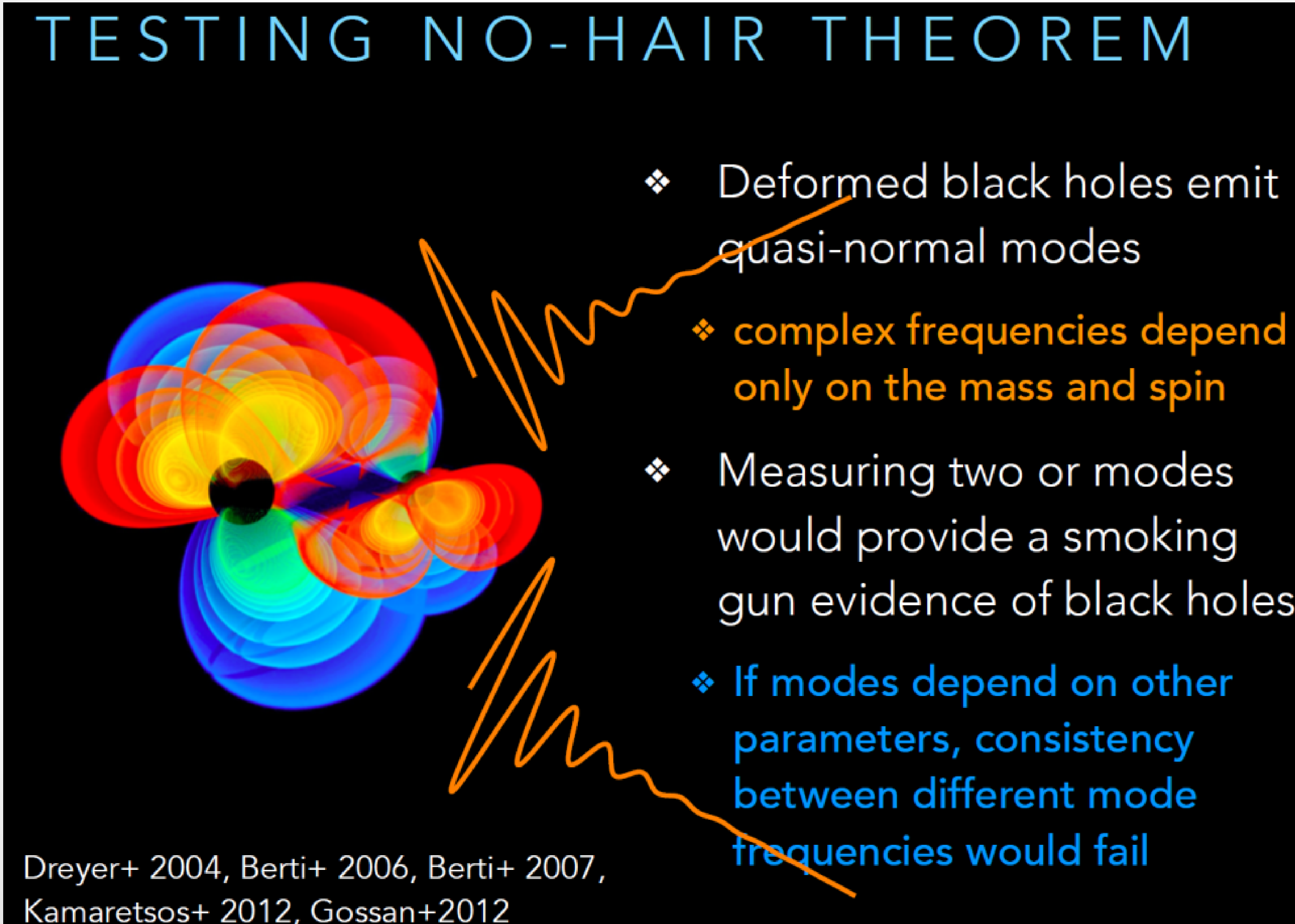
Links to GRB

- Short or long GRBs are GW (potential) emitter
- Fraction of BNS and NSBH in the short GRB progenitors
- Is it depending on distance ?
- Proportion with kilonova emission
- Relationship between jet and spin/masses ?
- See talks this afternoon and tomorrow



Kasen et al Nature 551(7678) 2017

Black hole physics

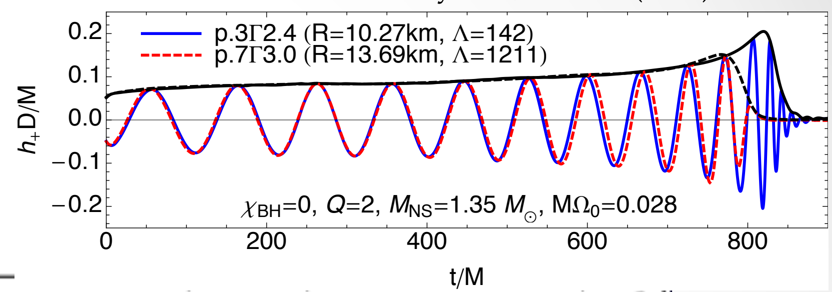


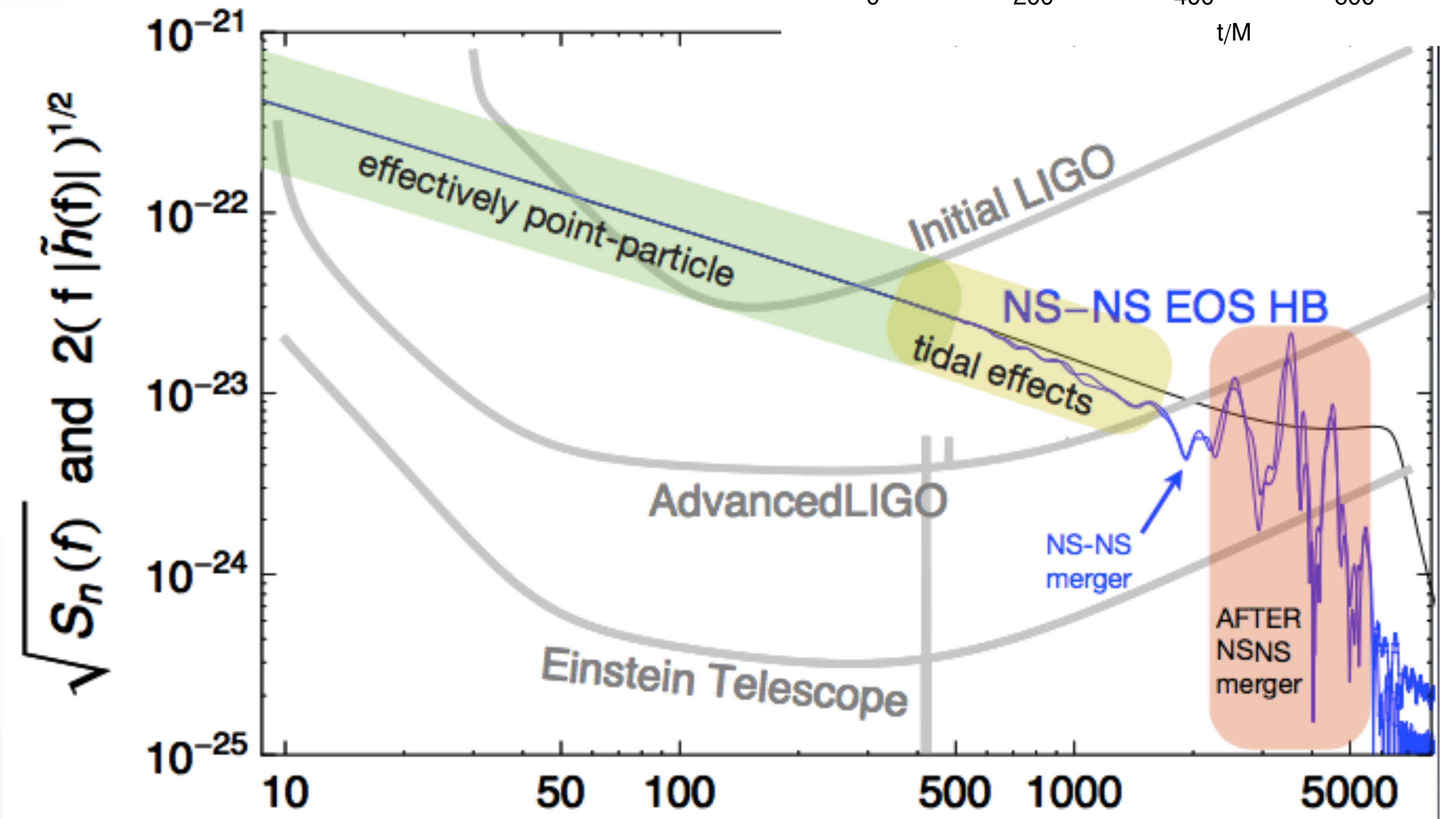
Credit:B.Sathyaprakash

Studying neutron stars

- Either isolated or in coalescing phase
- Full phenomena using EM and GW emission

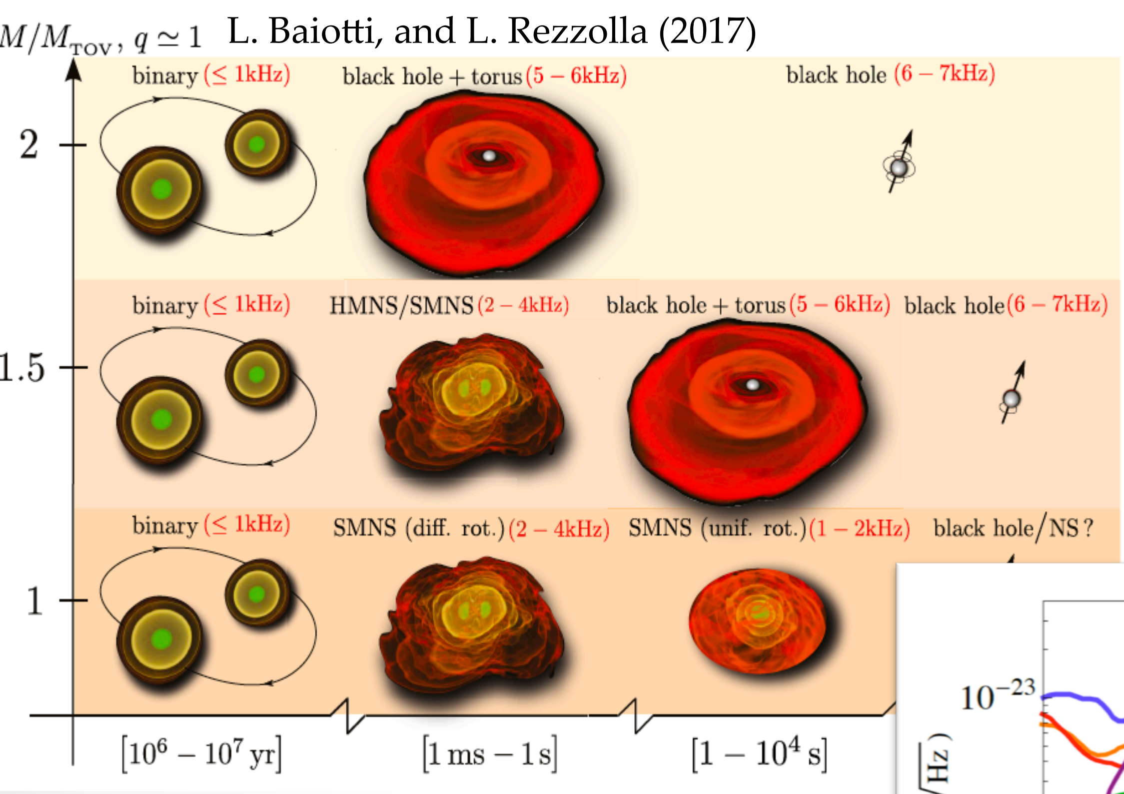
Lackey et al, PRD 89 (2014)





Credit: J Read

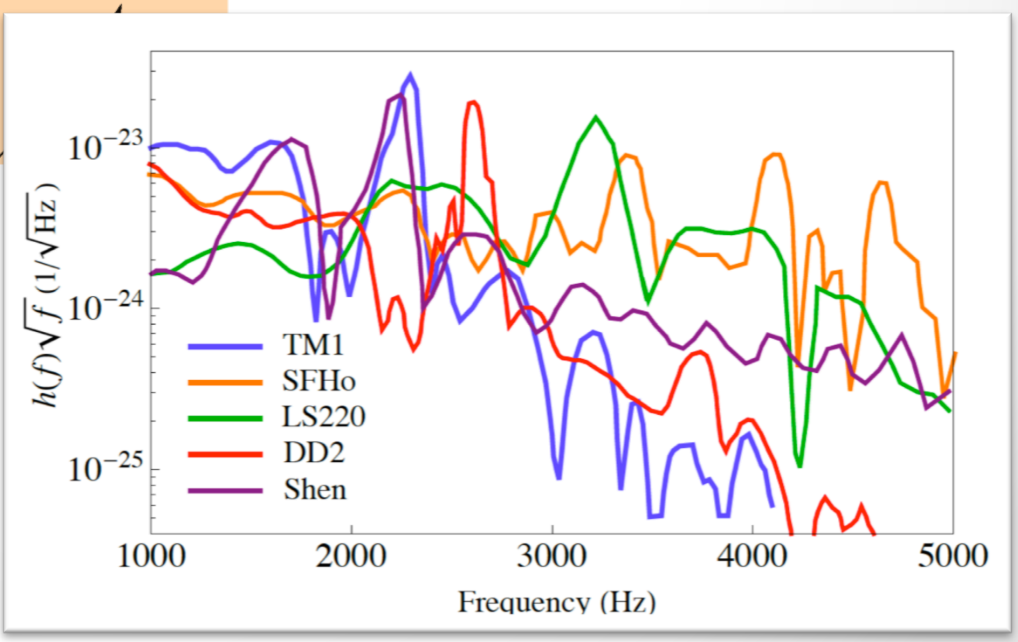
Post merger BNS object



- Hyper-massive neutron star
- Super-massive neutron star
- Black-hole

Oscillation frequency around few kHz

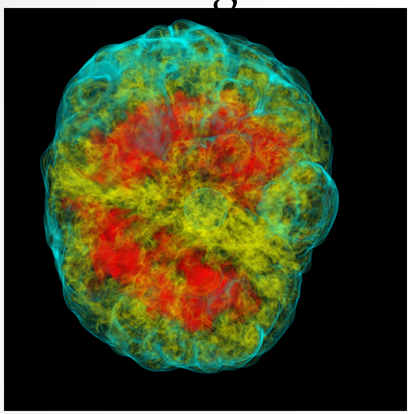
Depend on EOS and final object



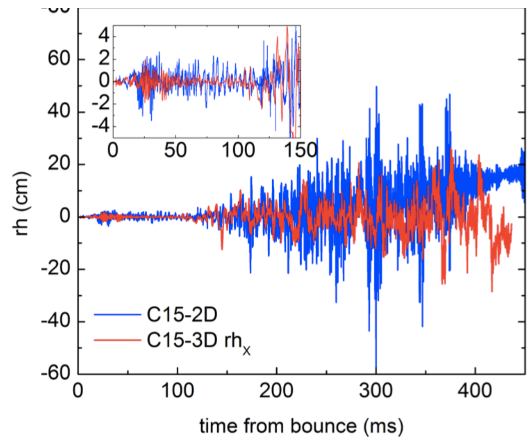
Core collapse SN

SN Ib, Ic, II

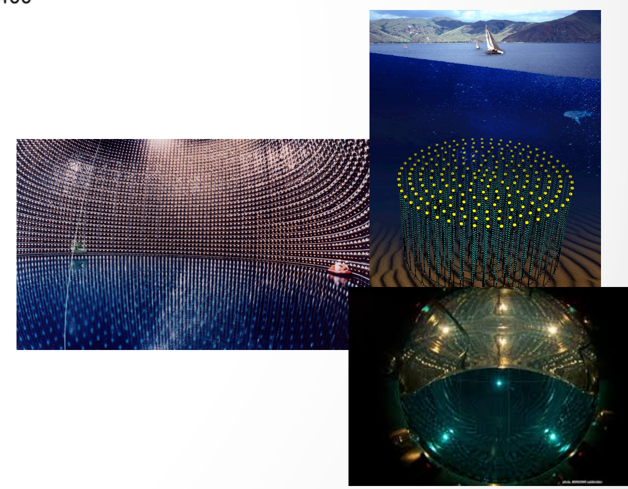
Central engine



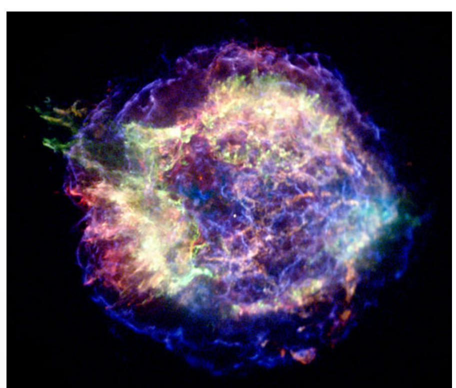
GW emission
0 - 1 s



Neutrino emission few ms to
10s



Explosion reaches
surface few s to
days after bounce



EM emission can last
years after bounce

Adapted from J. Gill, SN workshop 2017

A large diversity of phenomena

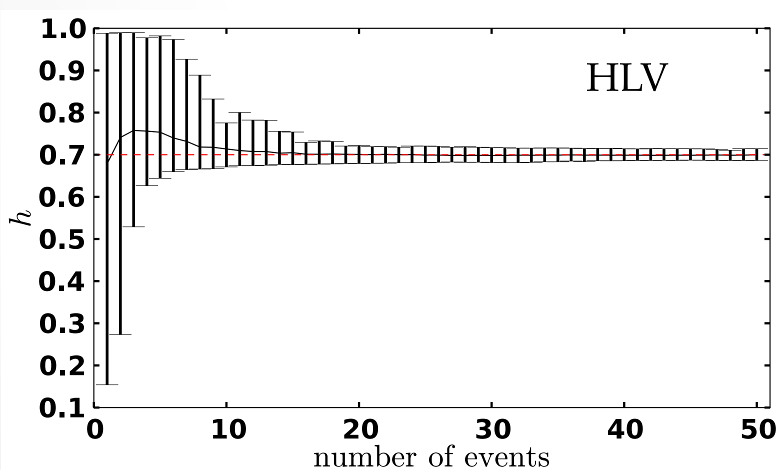
Emission Process	Duration [ms]	Spectrum [Hz]	*h* @ 1 Mpc	E_{GW} [$M_{\odot}c^2$]
Rotating Collapse & Bounce	~10	~400 - 900	~5×10^{-24} - 2×10^{-22}	~2×10^{-11} - 1×10^{-7}
Dynamical Shear	10 - ≳ 100	~700 - 1000	~ few $\times10^{-23}$	10^{-7} (change in time/100ms)
Bar Mode	10 - ≳ 100	~1000 - 2000	~ few $\times10^{-23}$ - $\times10^{-21}$	10^{-7} - 10^{-2} (change in time/100ms)
Prompt Convection	10 - 30	~50 - 1000	~ $\times10^{-25}$ - $\times10^{-23}$	10^{-12} - 10^{-9}
ν-driven Convection/ SASI	100 - 500	~100 - 1000	~ $\times10^{-25}$ - $\times10^{-23}$	10^{-12} - 10^{-9} (change in time/100ms)
Convection in PNS	≳ 1000	~600 - 1000	~ $\times10^{-25}$ - $\times10^{-23}$	10^{-8} (change in time/100ms)
BH Formation	≲ 1 - 2	~600 - 4000	~ $\times10^{-23}$ - $\times10^{-22}$	~10^{-8} - 10^{-7}
Aspherical Outflows	≳ 100 - 1000	~ 20	~ $\times10^{-23}$ - $\times10^{-22}$	≲ 10^{-11}
Accretion Disk Instabilities	≳ 1000	~100 - 1000	~ $\times10^{-22}$ - $\times10^{-19}$	~10^{-5} - 10^{-1}

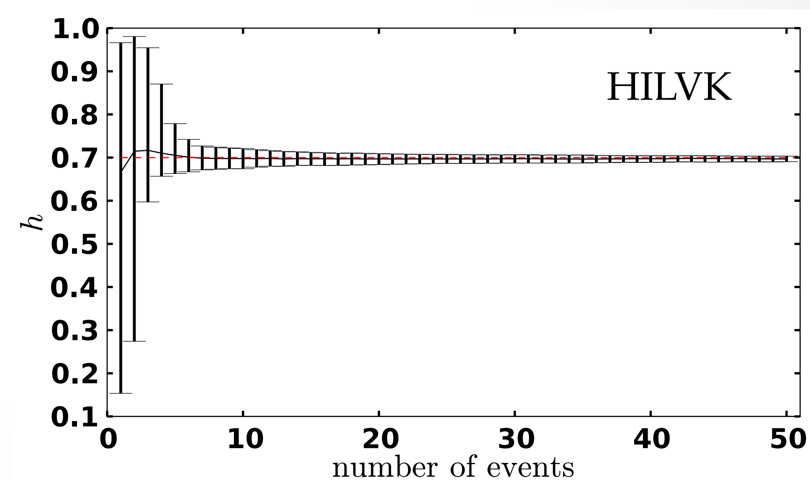
J. Gill, SN workshop 2017

Cosmological parameters

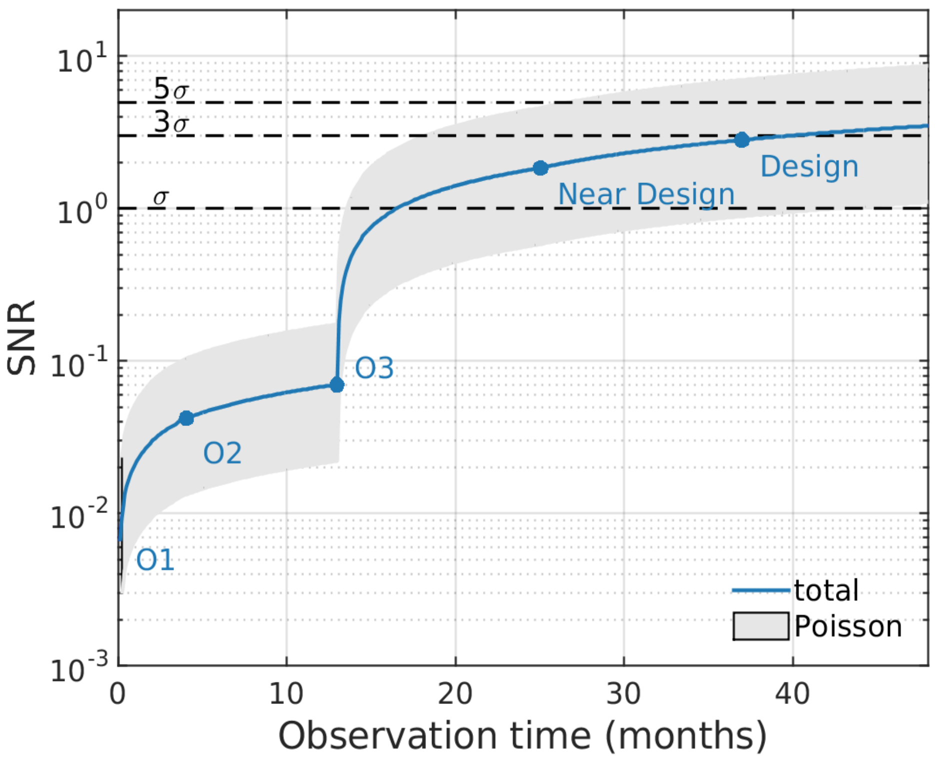
- Amplitude of GW coalescing signal is 1/D
- Can measure Hubble constant in local universe:
  - GW provide distance
  - EM counterpart provide redshift
- A perfect example GW170817, see Nial's presentation
- Need few tens of events to have accuracy around 1 %

Del Pozzo, PRD 86, 043011 (2012)





Stochastic background



Expected SNR for astrophysical stochastic signal

- Signal coming from sum of astrophysical sources:
  - Too far CBC events to be detected independently
  - Will provide constraints on population evolution scenarios
- Signal from cosmological origin
  - Post big bang emission
  - Signal strength not really known

What can we discover during SVOM era (2020-2030)?

- Detection of NSBH and accurate measurements on rate of coalescing events
- Several GRB detections
- With some luck first supernovae detection
- Neutron star ellipticity is potentially very low and isolated neutron star may be detected only at the end of the period
- Constraints on EoS with at least neutron stars in coalescing binaries
- Will detect binary black holes at cosmological distances
- Constraints on population models
- Will make more tests of General Relativity
- Put independent constraints on cosmological parameters
- Stochastic background from astrophysical sources will be detected