Discussion on Science Goals

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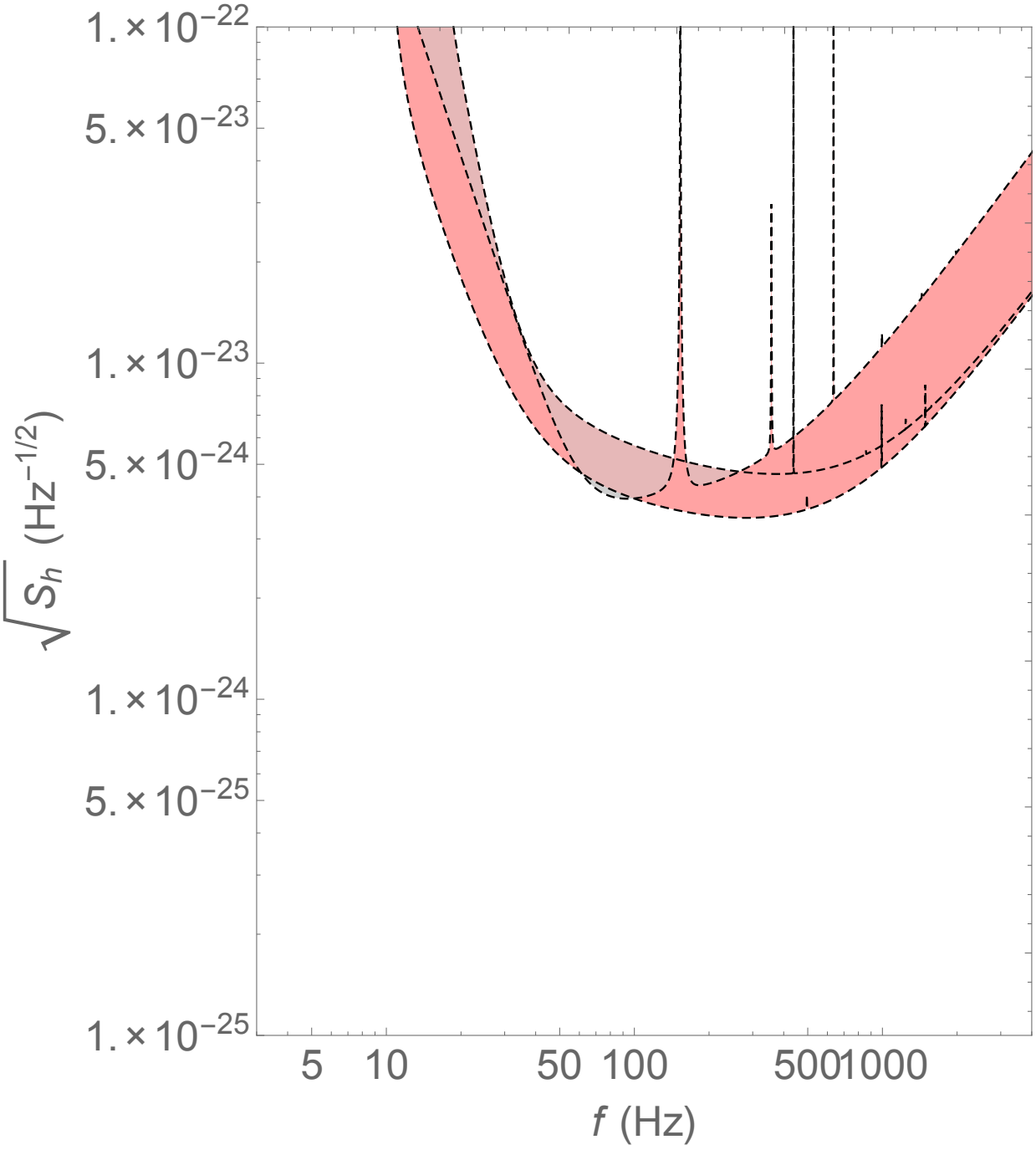
Overview

- **A scenario for the timeline of upgrade**
  - 2020-2025: pluses of LIGO (H,L), VIRGO++ and KaGRA+ (current detectors with squeezing)
  - 2025-2030: 3 LIGO Voyagers (H, L & I), VIRGO++ and KaGRA+
  - 2030: Einstein Telescope (ET)
  - 2035+: Cosmic Explorer (CE)

- **Strategy toward the science case**
  - **Unprecedented**, **compelling**, and **bold** case for each upgrade
  - Something **new** has to be proposed for each substantial upgrade
  - A strong case should have a **short** list of highlights

Scenarios of Upgrade



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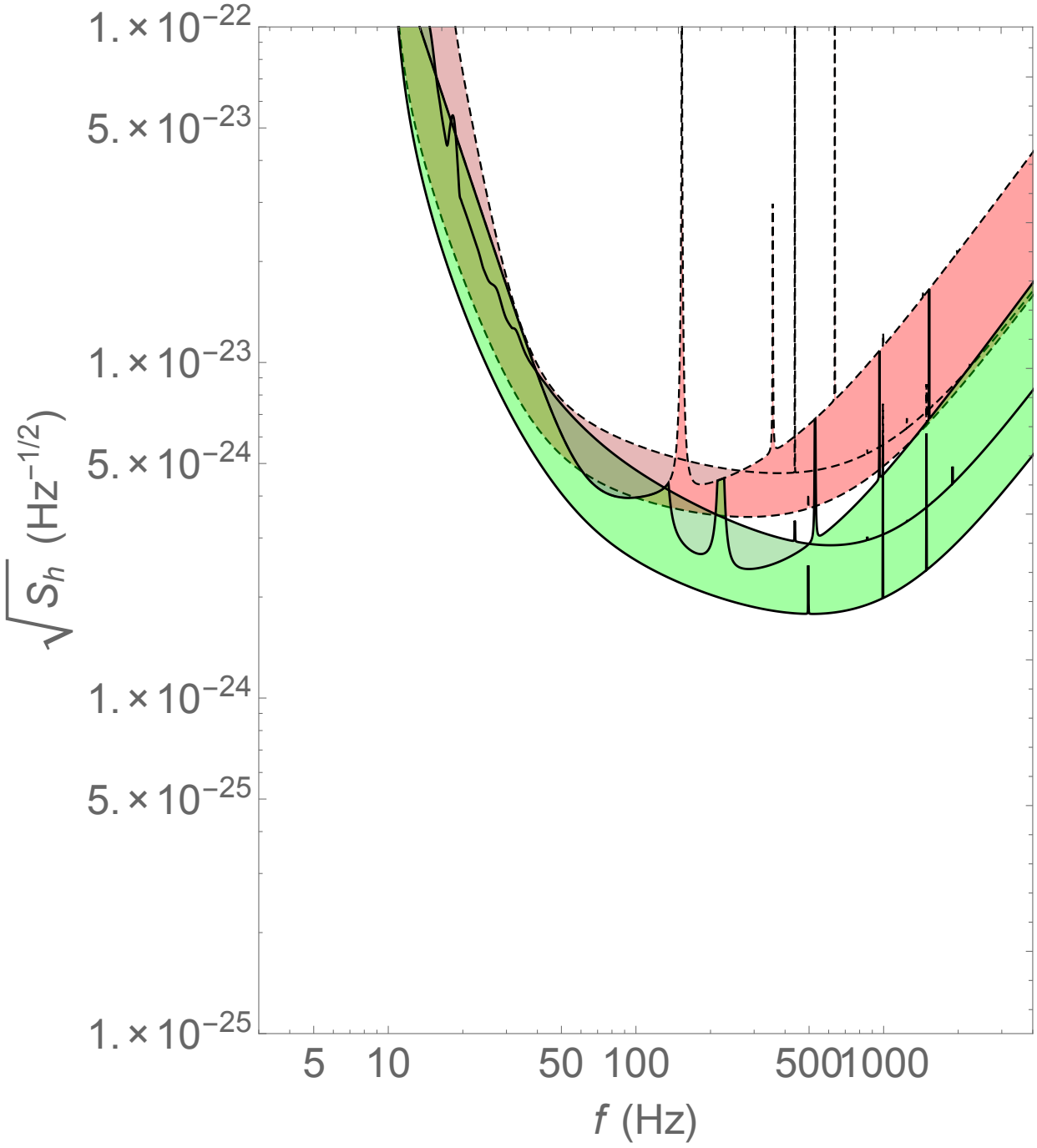
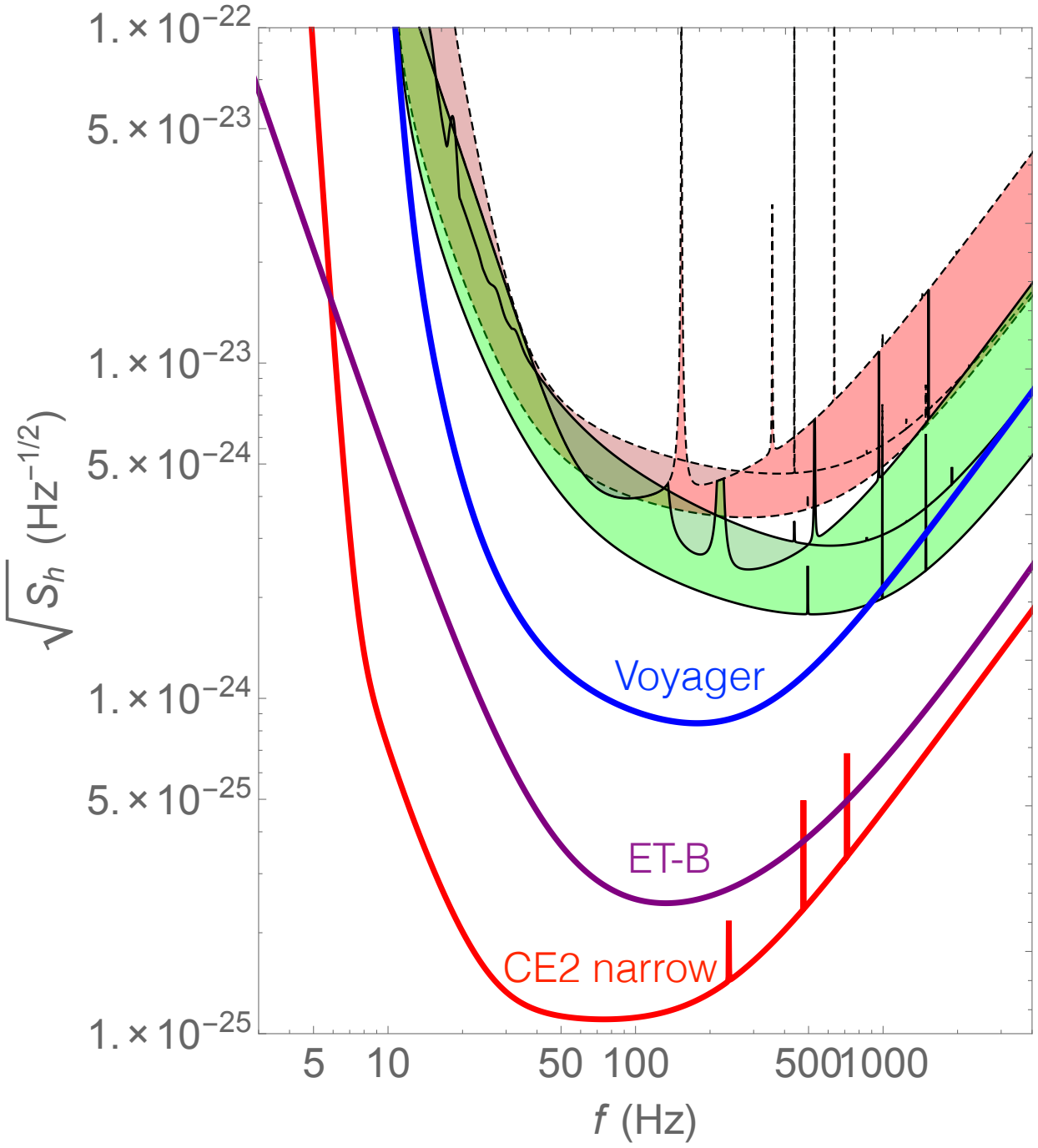


2020 -2025	A+ (LIGO-H & LIGO-L) VIRGO+++ KaGRA+ 3x @ high frequencies
2025 - 2030	3 Voyagers (L, H & I) 3- 4x overall VIRGO+++ KaGRA+
2030	Adding ET 10 x overall, 10 Hz *how many ETs, where?* *roles of 4km ifos?*
2035-	Adding CE 30x overall, 10 Hz *how many CEs, where?* *roles of 4km ifos & ET?*

VIRGO+++: Eleonora Capocasa
KaGRA+: Kentaro Somiya

Scenarios of Upgrade



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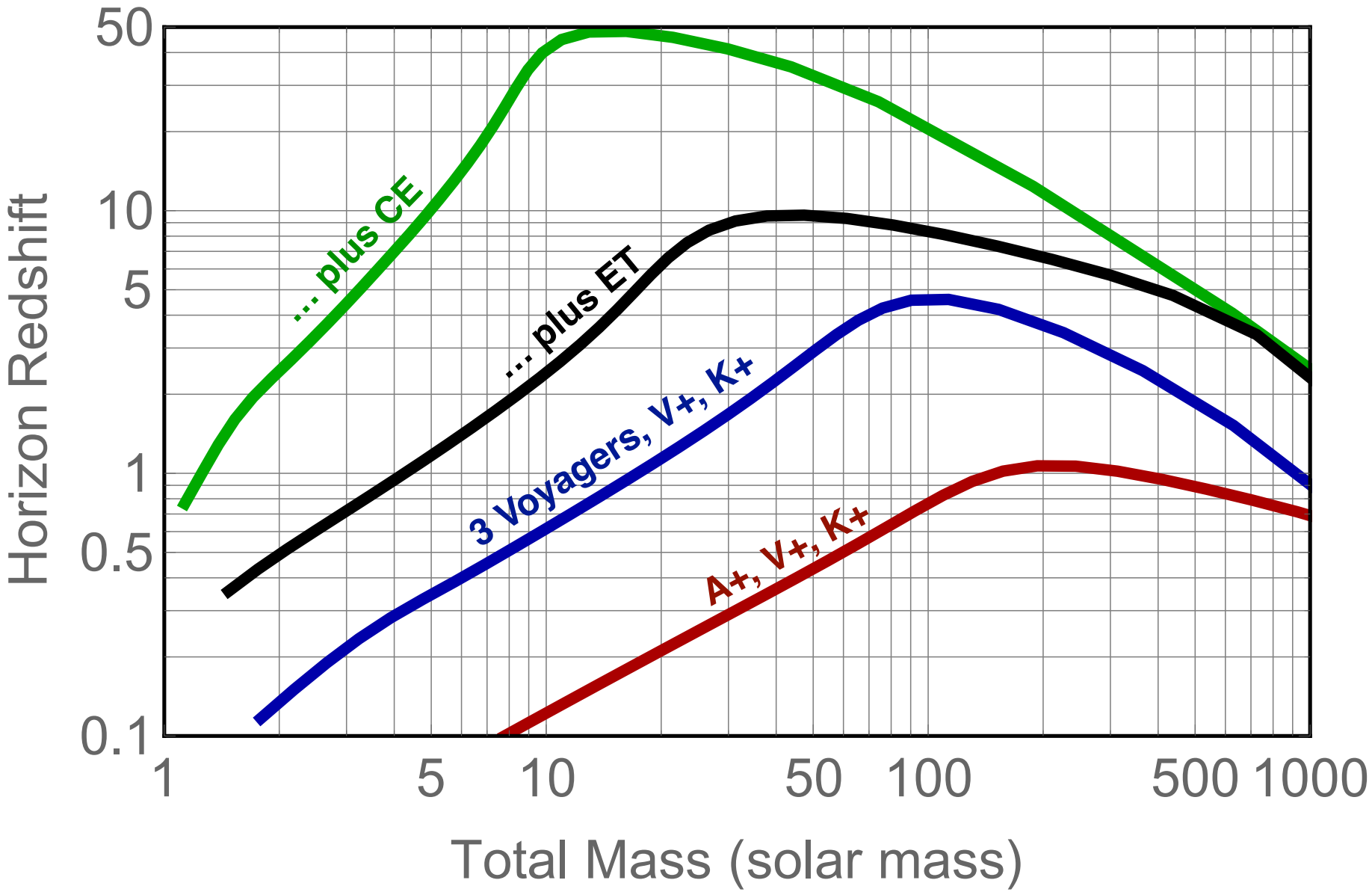
Science Cases?

	Extreme Physics (Gravity/GR)	Extreme Matter (Astrophysics)	Cosmic History (Cosmology)
A+, VIRGO+++, KaGRA+ (3x at high freq)			
3 Voyagers VIRGO+++, KaGRA+ (3x - 4x overall)			
plus ET (10x overall, down to ~5 Hz)			
plus CE (10x overall, down to ~5 Hz)			

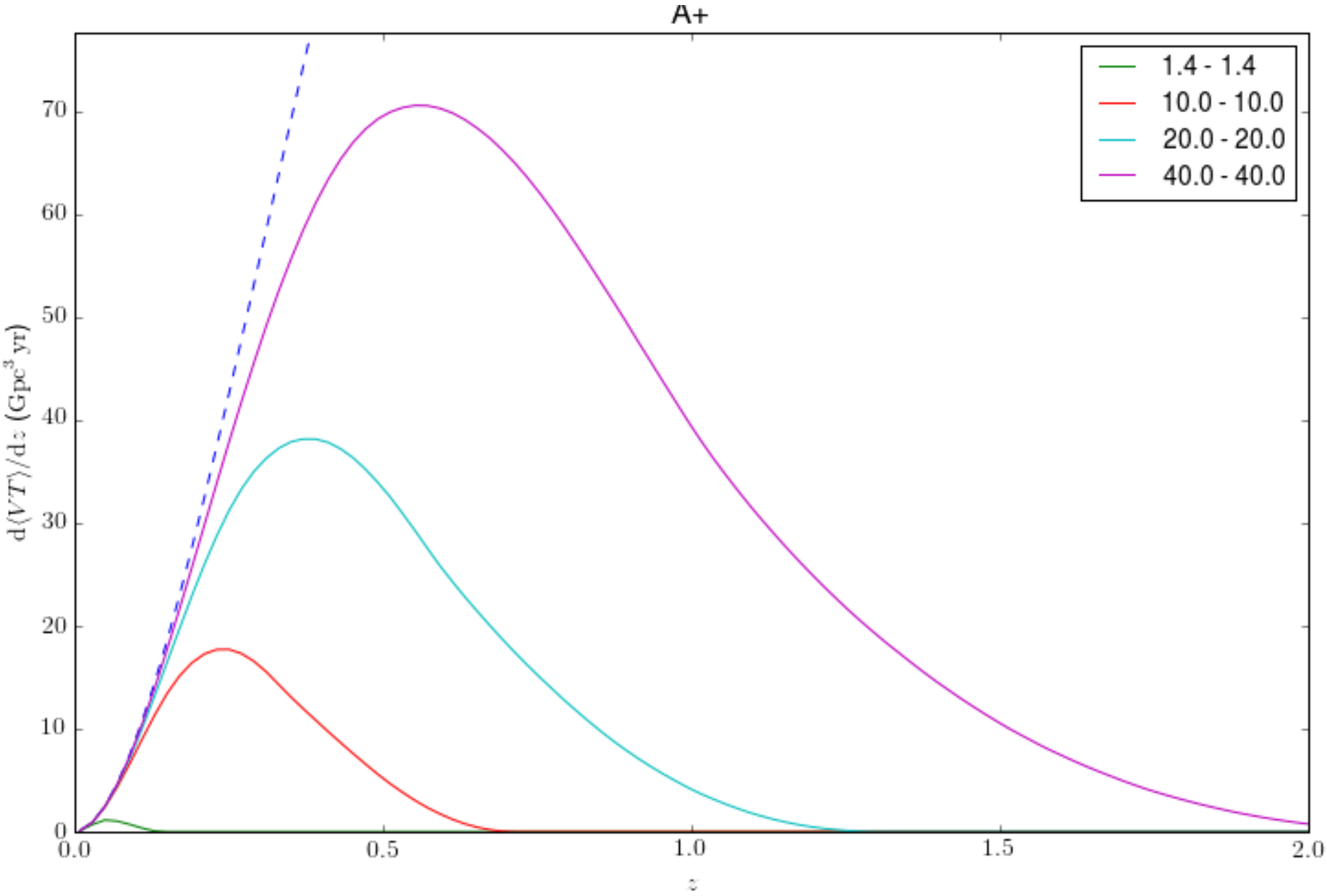
Populate this table with the following items
(most already discussed by Sathya & Steve on Monday)

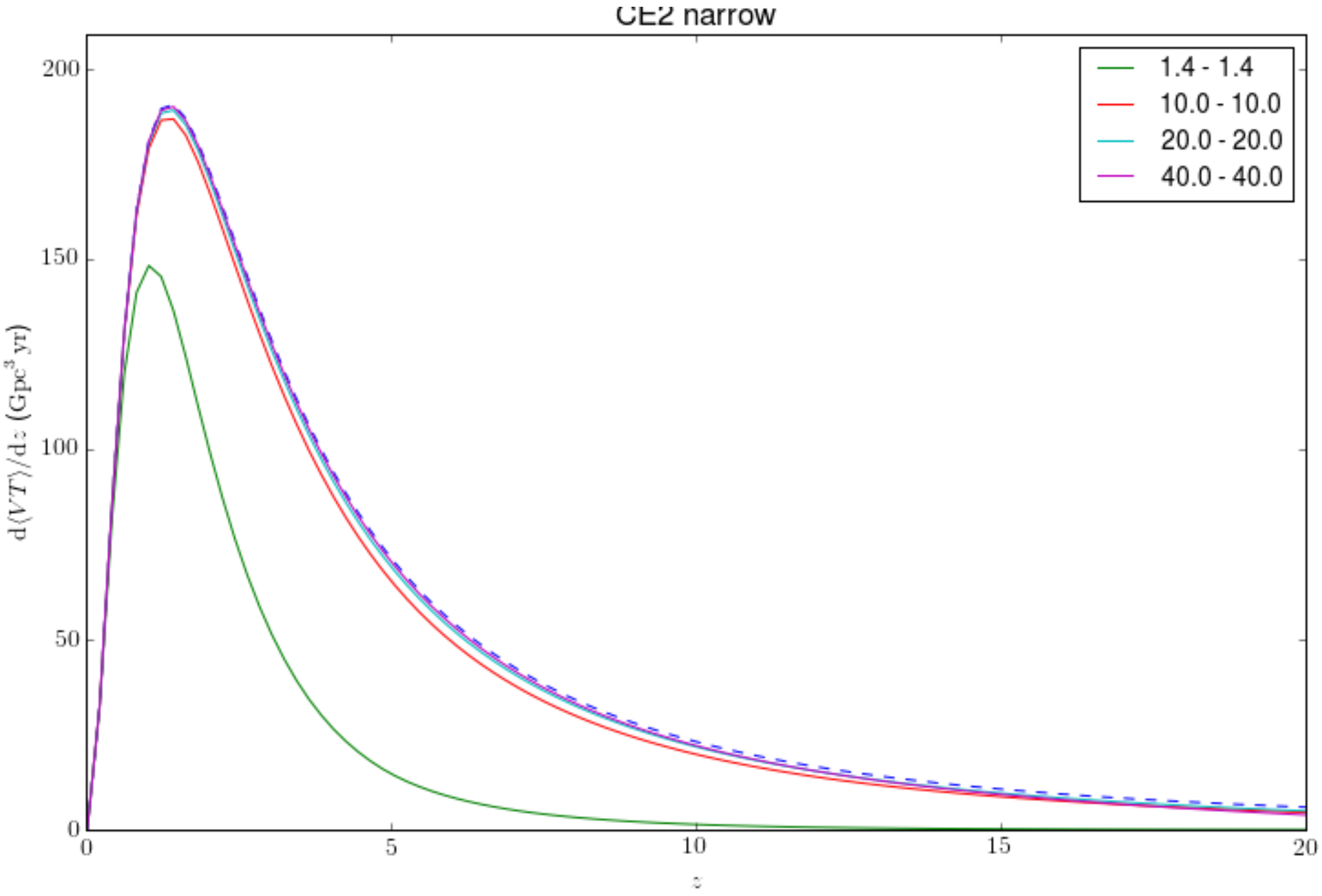
Horizon Distance for Equal-Mass Binaries



Science Case Example: Cosmic History

	Extreme Physics (Gravity/GR)	Extreme Matter (Astrophysics)	Cosmic History (Cosmology)
A+, VIRGO+++, KaGRA+ (3x at high freq)			
3 Voyagers, VIRGO+++, KaGRA+ (3x - 4x overall)			
plus ET (10x overall, down to ~5 Hz)			accessing BBH population during re-ionization
plus CE (10x overall, down to ~5 Hz)			map BBH throughout the universe, use this to probe cosmic history


A+
1.4 - 1.4
10.0 - 10.0
20.0 - 20.0
40.0 - 40.0
$\mathrm{d}\langle VT\rangle/\mathrm{d}z$ (Gpc^3 yr)
z
0
10
20
30
40
50
60
70
0.0
0.5
1.0
1.5
2.0


CE2 narrow
1.4 - 1.4
10.0 - 10.0
20.0 - 20.0
40.0 - 40.0
200
150
100
50
0
0
5
10
15
20
z
$\mathrm{d}\langle VT\rangle/\mathrm{d}z\ (\mathrm{Gpc}^3\,\mathrm{yr})$

SNR for GW150914-like Event @ 1Gpc

~10/year

A+, V+, K+	50
3 Voyager, V+, K+	200
plus ET	500
plus CE	2000

Science Case Example: Extreme Physics

	Extreme Physics (Gravity/GR)	Extreme Matter (Astrophysics)	Cosmic History (Cosmology)
A+, VIRGO+++, KaGRA+ (3x at high freq)			
3 Voyagers, VIRGO+++, KaGRA+ (3x - 4x overall)	disentangle next QNM		
plus ET (10x overall, down to ~5 Hz)	test QNM		accessing BBH population during re-ionization
plus CE (10x overall, down to ~5 Hz)			map BBH throughout the universe, use this to probe cosmic history

Cosmic History

1. Mapping the history of black hole formation, via statistics of individual binaries, and stochastic background (the latter sees much higher *z*).
2. An independent way for providing a standard siren. If this is from BBH, can we disentangle evolution in BBH population and cosmic expansion history?
3. High-z NSBH and NSNS binaries telling the content of the universe?
4. Propagation of gravitational wave through the universe: laws of propagation, space-time geometry. Does GW “sees” the same universe as light?

Extreme Matter

1. Are NS binaries progenitors for short GRB? GRB physics from GW-EM observations.
2. BBH Population: trace formations/evolutions of massive stars? Galaxies (from binary massive stars) or globular clusters (dynamically)?
3. Populations of BNS/NSBH, what do they tell us?
4. EOS of Stationary neutron star: tidal deformation and NS radius.
5. Dynamics of the neutron-star interior, tidal instabilities.
6. Nature of LMXB from continuous-waves observation.
7. Neutron star structure from isolated neutron stars emitting CW.
8. Supernova.

Extreme Gravity

1. Additional QNMs for testing no-hair theorem.
2. Demonstrating GR features in BBH [memory, kick, BH absorption/superradiance, etc.]
3. Testing alternative theories [specific modifications of GR]
4. Searching for deviations from GR [e.g., PN coefficients, compatibility between early and late waveforms, GW propagation]
5. Probing space-time geometry near of black hole horizon and its existence (e.g., gravastars)
6. Bursts and stochastic background from cosmic strings.
7. Probing phase transitions in the early universe.