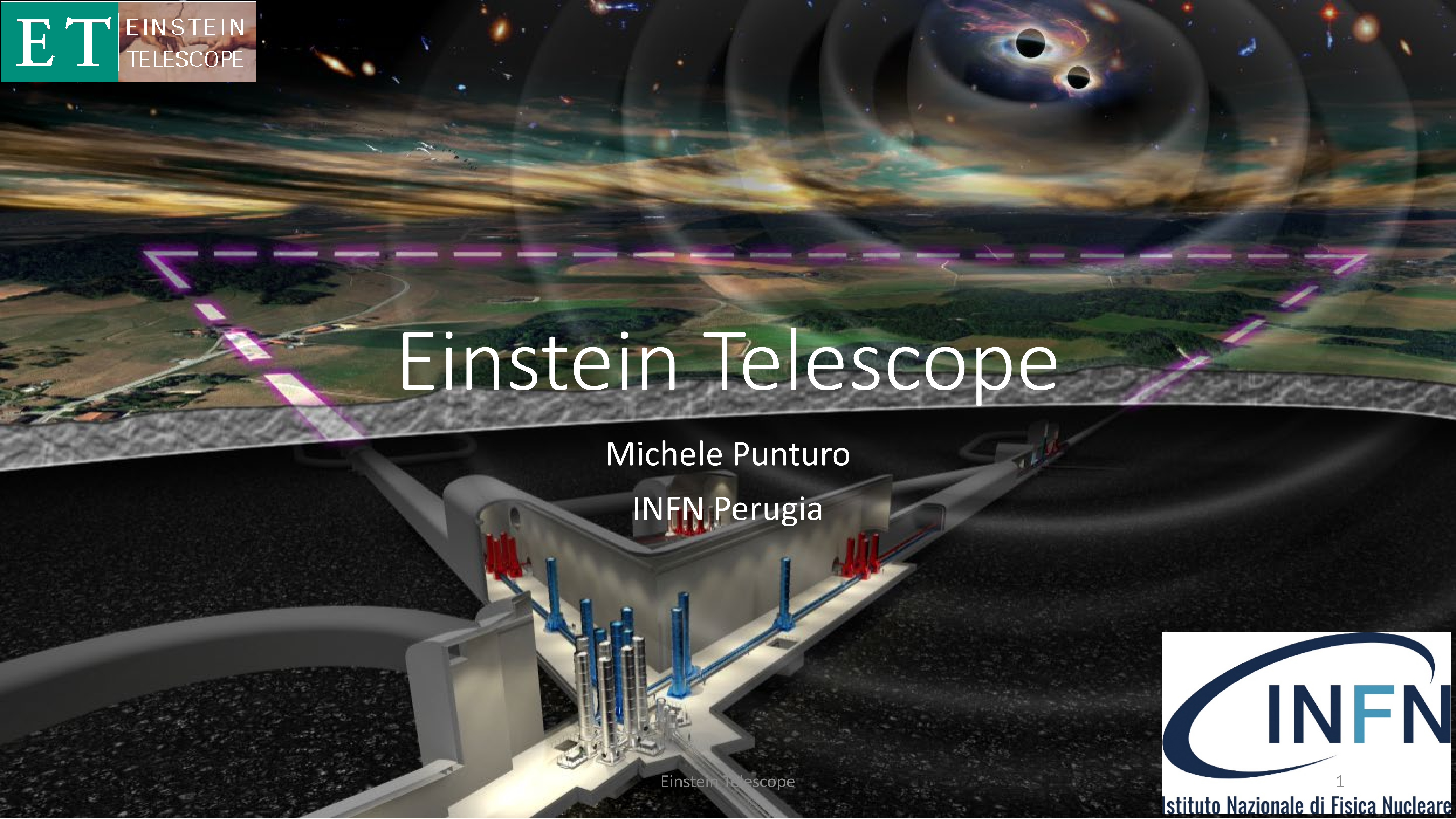


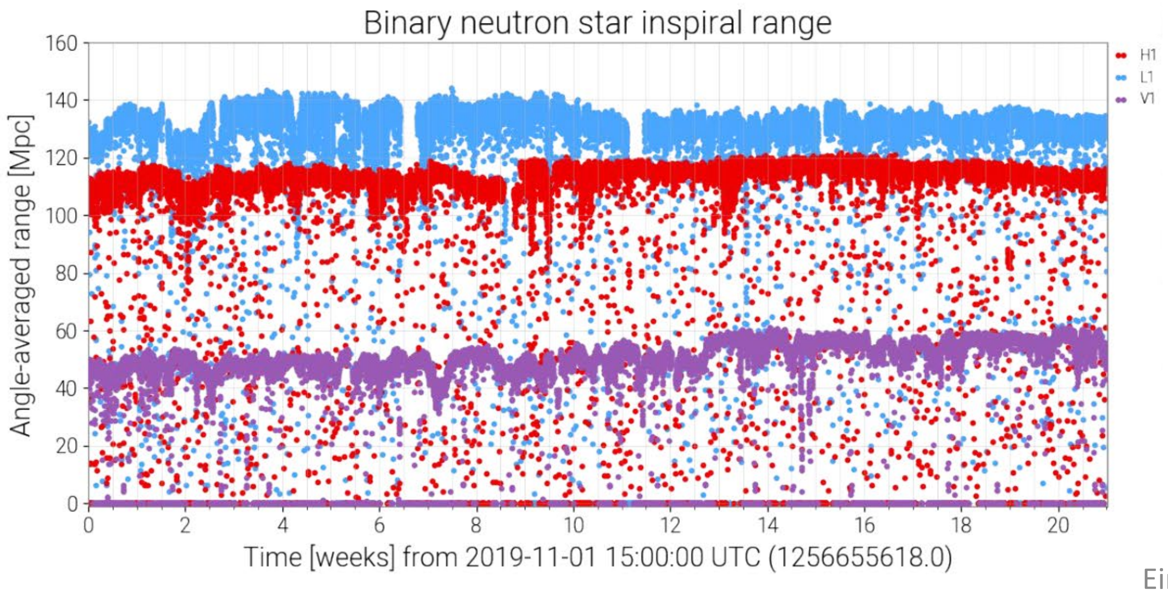
Einstein Telescope

Michele Punturo

INFN Perugia

LIGO/Virgo/KAGRA O3 Run

- 11 months of data taking
- 56 public alerts
- 39 candidates published in the O3a catalogue

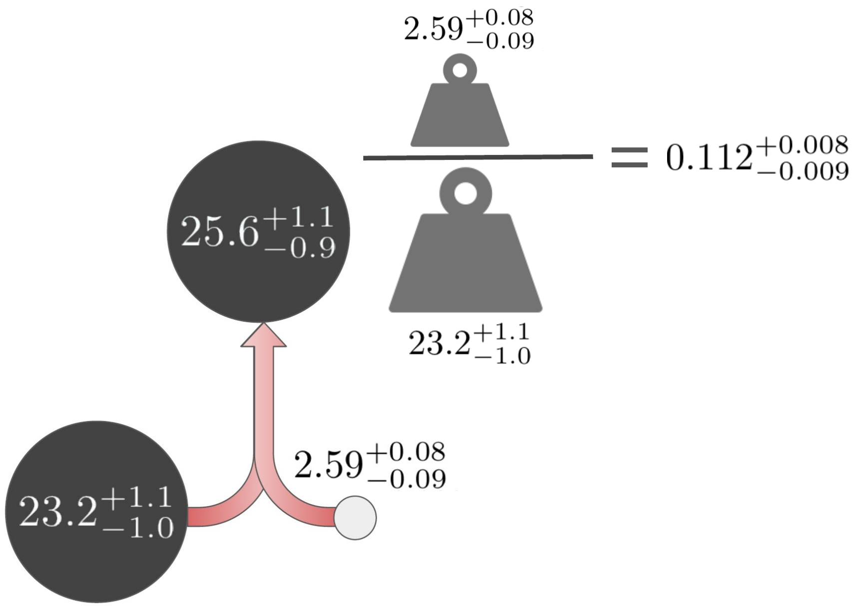


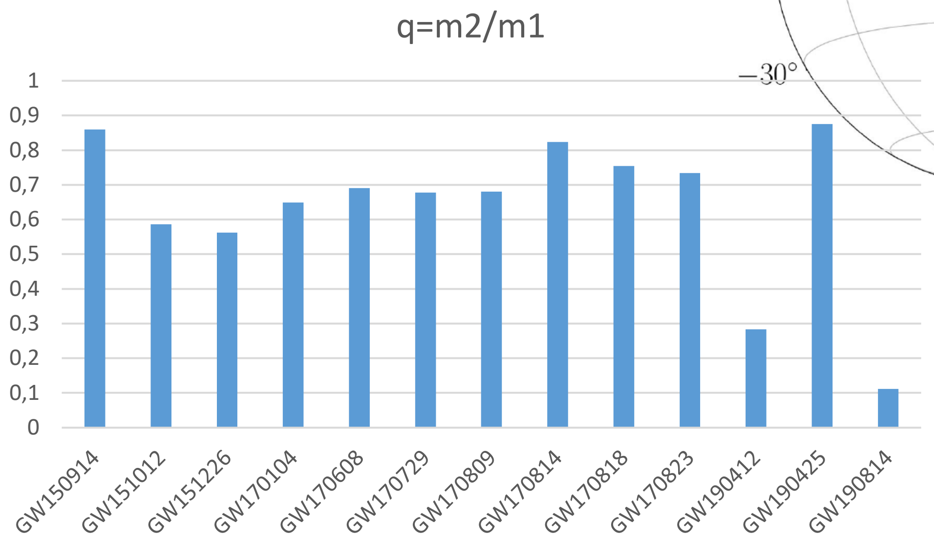
Einstein Tele

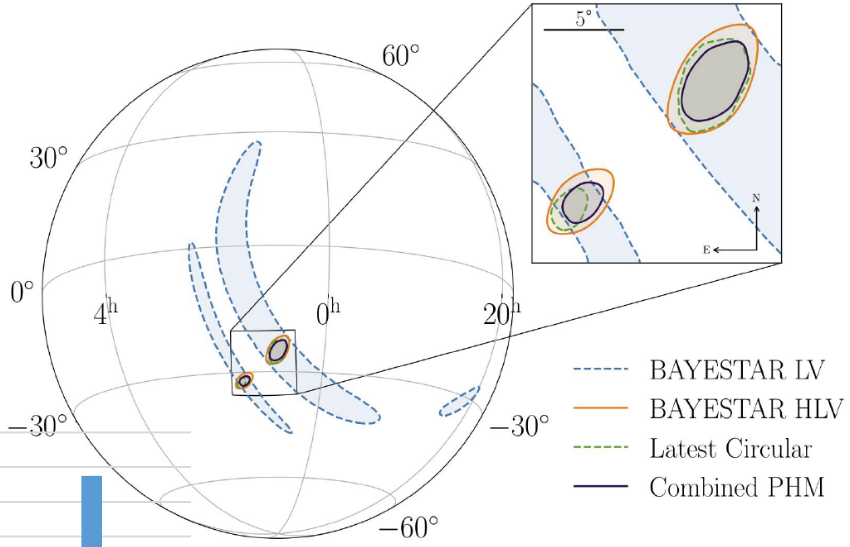
Event	M ($M_\odot$)	$\mathcal{M}$ ($M_\odot$)	m_1 ($M_\odot$)	m_2 ($M_\odot$)	$\chi_{\rm eff}$	$D_{\rm L}$ (Gpc)	z	$M_{\rm f}$ ($M_\odot$)	$\chi_{\rm f}$	$\Delta\Omega$ (deg^2)	SNR
GW190408_181802	$43.0^{+4.2}_{-3.0}$	$18.3^{+1.9}_{-1.2}$	$24.6^{+5.1}_{-3.4}$	$18.4^{+3.3}_{-3.6}$	$-0.03^{+0.14}_{-0.19}$	$1.55^{+0.40}_{-0.60}$	$0.29^{+0.06}_{-0.10}$	$41.1^{+3.9}_{-2.8}$	$0.67^{+0.06}_{-0.07}$	150	$15.3^{+0.2}_{-0.3}$
GW190412	$38.4^{+3.8}_{-3.7}$	$13.3^{+0.4}_{-0.3}$	$30.1^{+4.7}_{-5.1}$	$8.3^{+1.6}_{-0.9}$	$0.25^{+0.08}_{-0.11}$	$0.74^{+0.14}_{-0.17}$	$0.15^{+0.03}_{-0.03}$	$37.3^{+3.9}_{-3.8}$	$0.67^{+0.05}_{-0.06}$	21	$18.9^{+0.2}_{-0.3}$
GW190413_052954	$58.6^{+13.3}_{-9.7}$	$24.6^{+5.5}_{-4.1}$	$34.7^{+12.6}_{-8.1}$	$23.7^{+7.3}_{-6.7}$	$-0.01^{+0.29}_{-0.34}$	$3.55^{+2.27}_{-1.66}$	$0.59^{+0.29}_{-0.24}$	$56.0^{+12.5}_{-9.2}$	$0.68^{+0.12}_{-0.13}$	1500	$8.9^{+0.4}_{-0.7}$
GW190413_134308	$78.8^{+17.4}_{-11.9}$	$33.0^{+8.2}_{-5.4}$	$47.5^{+13.5}_{-10.7}$	$31.8^{+11.7}_{-10.8}$	$-0.03^{+0.25}_{-0.29}$	$4.45^{+2.48}_{-2.12}$	$0.71^{+0.31}_{-0.30}$	$75.5^{+16.4}_{-11.4}$	$0.68^{+0.10}_{-0.12}$	730	$10.0^{+0.4}_{-0.5}$
GW190421_213856	$72.9^{+13.4}_{-9.2}$	$31.2^{+5.9}_{-4.2}$	$41.3^{+10.4}_{-6.9}$	$31.9^{+8.0}_{-8.8}$	$-0.06^{+0.22}_{-0.27}$	$2.88^{+1.37}_{-1.38}$	$0.49^{+0.19}_{-0.21}$	$69.7^{+12.5}_{-8.7}$	$0.67^{+0.10}_{-0.11}$	1200	$10.7^{+0.2}_{-0.4}$
GW190424_180648	$72.6^{+13.3}_{-10.7}$	$31.0^{+5.8}_{-4.6}$	$40.5^{+11.1}_{-7.3}$	$31.8^{+7.6}_{-7.7}$	$0.13^{+0.22}_{-0.22}$	$2.20^{+1.58}_{-1.16}$	$0.39^{+0.23}_{-0.19}$	$68.9^{+12.4}_{-10.1}$	$0.74^{+0.09}_{-0.09}$	28000	$10.4^{+0.2}_{-0.4}$
GW190425	$3.4^{+0.3}_{-0.1}$	$1.44^{+0.02}_{-0.02}$	$2.0^{+0.6}_{-0.3}$	$1.4^{+0.3}_{-0.3}$	$0.06^{+0.11}_{-0.05}$	$0.16^{+0.07}_{-0.07}$	$0.03^{+0.01}_{-0.02}$	–	–	10000	$12.4^{+0.3}_{-0.4}$
GW190426_152155	$7.2^{+3.5}_{-1.5}$	$2.41^{+0.08}_{-0.08}$	$5.7^{+3.9}_{-2.3}$	$1.5^{+0.8}_{-0.5}$	$-0.03^{+0.32}_{-0.30}$	$0.37^{+0.18}_{-0.16}$	$0.08^{+0.04}_{-0.03}$	–	–	1300	$8.7^{+0.5}_{-0.6}$
GW190503_185404	$71.7^{+9.4}_{-8.3}$	$30.2^{+4.2}_{-4.2}$	$43.3^{+9.2}_{-8.1}$	$28.4^{+7.7}_{-8.0}$	$-0.03^{+0.20}_{-0.26}$	$1.45^{+0.69}_{-0.63}$	$0.27^{+0.11}_{-0.11}$	$68.6^{+8.8}_{-7.7}$	$0.66^{+0.09}_{-0.12}$	94	$12.4^{+0.2}_{-0.3}$
GW190512_180714	$35.9^{+3.8}_{-3.5}$	$14.6^{+1.3}_{-1.0}$	$23.3^{+5.3}_{-5.8}$	$12.6^{+3.6}_{-2.5}$	$0.03^{+0.12}_{-0.13}$	$1.43^{+0.55}_{-0.55}$	$0.27^{+0.09}_{-0.10}$	$34.5^{+3.8}_{-3.5}$	$0.65^{+0.07}_{-0.07}$	220	$12.2^{+0.2}_{-0.4}$
GW190513_205428	$53.9^{+8.6}_{-5.9}$	$21.6^{+3.8}_{-1.9}$	$35.7^{+9.5}_{-9.2}$	$18.0^{+7.7}_{-4.1}$	$0.11^{+0.28}_{-0.17}$	$2.06^{+0.88}_{-0.80}$	$0.37^{+0.13}_{-0.13}$	$51.6^{+8.2}_{-5.8}$	$0.68^{+0.14}_{-0.12}$	520	$12.9^{+0.3}_{-0.4}$
GW190514_065416	$67.2^{+18.7}_{-10.8}$	$28.5^{+7.9}_{-4.8}$	$39.0^{+14.7}_{-8.2}$	$28.4^{+9.3}_{-8.8}$	$-0.19^{+0.29}_{-0.32}$	$4.13^{+2.65}_{-2.17}$	$0.67^{+0.33}_{-0.31}$	$64.5^{+17.9}_{-10.4}$	$0.63^{+0.11}_{-0.15}$	3000	$8.2^{+0.3}_{-0.6}$
GW190517_055101	$63.5^{+9.6}_{-9.6}$	$26.6^{+4.0}_{-4.0}$	$37.4^{+11.7}_{-7.6}$	$25.3^{+7.0}_{-7.3}$	$0.52^{+0.19}_{-0.19}$	$1.86^{+1.62}_{-0.84}$	$0.34^{+0.24}_{-0.14}$	$59.3^{+9.1}_{-8.9}$	$0.87^{+0.05}_{-0.07}$	470	$10.7^{+0.4}_{-0.6}$
GW190519_153544	$106.6^{+13.5}_{-14.8}$	$44.5^{+6.4}_{-7.1}$	$66.0^{+10.7}_{-12.0}$	$40.5^{+11.0}_{-11.1}$	$0.31^{+0.20}_{-0.22}$	$2.53^{+1.83}_{-0.92}$	$0.44^{+0.25}_{-0.14}$	$101.0^{+12.4}_{-13.8}$	$0.79^{+0.07}_{-0.13}$	860	$15.6^{+0.2}_{-0.3}$
GW190521	$163.9^{+39.2}_{-23.5}$	$69.2^{+17.0}_{-10.6}$	$95.3^{+28.7}_{-18.9}$	$69.0^{+22.7}_{-23.1}$	$0.03^{+0.32}_{-0.39}$	$3.92^{+2.19}_{-1.95}$	$0.64^{+0.28}_{-0.28}$	$156.3^{+36.8}_{-22.4}$	$0.71^{+0.12}_{-0.16}$	1000	$14.2^{+0.3}_{-0.3}$
GW190521_074359	$74.7^{+7.0}_{-4.8}$	$32.1^{+3.2}_{-2.5}$	$42.2^{+5.9}_{-4.8}$	$32.8^{+5.4}_{-6.4}$	$0.09^{+0.10}_{-0.13}$	$1.24^{+0.40}_{-0.57}$	$0.24^{+0.07}_{-0.10}$	$71.0^{+6.5}_{-4.4}$	$0.72^{+0.05}_{-0.07}$	550	$25.8^{+0.1}_{-0.2}$
GW190527_092055	$59.1^{+21.3}_{-9.8}$	$24.3^{+9.1}_{-4.2}$	$36.5^{+16.4}_{-9.0}$	$22.6^{+10.5}_{-8.1}$	$0.11^{+0.28}_{-0.28}$	$2.49^{+2.48}_{-1.24}$	$0.44^{+0.34}_{-0.20}$	$56.4^{+20.2}_{-9.3}$	$0.71^{+0.12}_{-0.16}$	3700	$8.1^{+0.3}_{-0.9}$
GW190602_175927	$116.3^{+19.0}_{-15.6}$	$49.1^{+9.1}_{-8.5}$	$69.1^{+15.7}_{-13.0}$	$47.8^{+14.3}_{-17.4}$	$0.07^{+0.25}_{-0.24}$	$2.69^{+1.79}_{-1.12}$	$0.47^{+0.25}_{-0.17}$	$110.9^{+17.7}_{-14.9}$	$0.70^{+0.10}_{-0.14}$	690	$12.8^{+0.2}_{-0.3}$
GW190620_030421	$92.1^{+18.5}_{-13.1}$	$38.3^{+8.3}_{-6.5}$	$57.1^{+16.0}_{-12.7}$	$35.5^{+12.2}_{-12.3}$	$0.33^{+0.22}_{-0.25}$	$2.81^{+1.68}_{-1.31}$	$0.49^{+0.23}_{-0.20}$	$87.2^{+16.8}_{-12.1}$	$0.79^{+0.08}_{-0.15}$	7200	$12.1^{+0.3}_{-0.4}$
GW190630_185205	$59.1^{+4.6}_{-4.8}$	$24.9^{+2.1}_{-2.1}$	$35.1^{+6.9}_{-5.6}$	$23.7^{+5.2}_{-5.1}$	$0.10^{+0.12}_{-0.13}$	$0.89^{+0.56}_{-0.37}$	$0.18^{+0.10}_{-0.07}$	$56.4^{+4.4}_{-4.6}$	$0.70^{+0.05}_{-0.07}$	1200	$15.6^{+0.2}_{-0.3}$
GW190701_203306	$94.3^{+12.1}_{-9.5}$	$40.3^{+5.4}_{-4.9}$	$53.9^{+11.8}_{-8.0}$	$40.8^{+8.7}_{-12.0}$	$-0.07^{+0.23}_{-0.29}$	$2.06^{+0.76}_{-0.73}$	$0.37^{+0.11}_{-0.12}$	$90.2^{+11.3}_{-8.9}$	$0.66^{+0.09}_{-0.13}$	46	$11.3^{+0.2}_{-0.3}$
GW190706_222641	$104.1^{+20.2}_{-13.9}$	$42.7^{+10.0}_{-7.0}$	$67.0^{+14.6}_{-16.2}$	$38.2^{+14.6}_{-13.3}$	$0.28^{+0.26}_{-0.29}$	$4.42^{+2.59}_{-1.93}$	$0.71^{+0.32}_{-0.27}$	$99.0^{+18.3}_{-13.5}$	$0.78^{+0.09}_{-0.18}$	650	$12.6^{+0.2}_{-0.4}$
GW190707_093326	$20.1^{+1.9}_{-1.3}$	$8.5^{+0.6}_{-0.5}$	$11.6^{+3.3}_{-1.7}$	$8.4^{+1.4}_{-1.7}$	$-0.05^{+0.10}_{-0.08}$	$0.77^{+0.38}_{-0.37}$	$0.16^{+0.07}_{-0.07}$	$19.2^{+1.9}_{-1.3}$	$0.66^{+0.03}_{-0.04}$	1300	$13.3^{+0.2}_{-0.4}$
GW190708_232457	$30.9^{+2.5}_{-1.8}$	$13.2^{+0.9}_{-0.6}$	$17.6^{+4.7}_{-2.3}$	$13.2^{+2.0}_{-2.7}$	$0.02^{+0.10}_{-0.08}$	$0.88^{+0.33}_{-0.39}$	$0.18^{+0.06}_{-0.07}$	$29.5^{+2.5}_{-1.8}$	$0.69^{+0.04}_{-0.04}$	14000	$13.1^{+0.2}_{-0.3}$
GW190719_215514	$57.8^{+18.3}_{-10.7}$	$23.5^{+6.5}_{-4.0}$	$36.5^{+18.0}_{-10.3}$	$20.8^{+9.0}_{-7.2}$	$0.32^{+0.29}_{-0.31}$	$3.94^{+2.59}_{-2.00}$	$0.64^{+0.33}_{-0.29}$	$54.9^{+17.3}_{-10.2}$	$0.78^{+0.11}_{-0.17}$	2900	$8.3^{+0.3}_{-0.8}$
GW190720_000836	$21.5^{+4.3}_{-2.3}$	$8.9^{+0.5}_{-0.8}$	$13.4^{+6.7}_{-3.0}$	$7.8^{+2.3}_{-2.2}$	$0.18^{+0.14}_{-0.12}$	$0.79^{+0.69}_{-0.32}$	$0.16^{+0.12}_{-0.06}$	$20.4^{+4.5}_{-2.2}$	$0.72^{+0.06}_{-0.05}$	460	$11.0^{+0.3}_{-0.7}$
GW190727_060333	$67.1^{+11.7}_{-8.0}$	$28.6^{+5.3}_{-3.7}$	$38.0^{+9.5}_{-6.2}$	$29.4^{+7.1}_{-8.4}$	$0.11^{+0.26}_{-0.25}$	$3.30^{+1.54}_{-1.50}$	$0.55^{+0.21}_{-0.22}$	$63.8^{+10.9}_{-7.5}$	$0.73^{+0.10}_{-0.10}$	830	$11.9^{+0.3}_{-0.5}$
GW190728_064510	$20.6^{+4.5}_{-1.3}$	$8.6^{+0.5}_{-0.3}$	$12.3^{+7.2}_{-2.2}$	$8.1^{+1.7}_{-2.6}$	$0.12^{+0.20}_{-0.07}$	$0.87^{+0.26}_{-0.37}$	$0.18^{+0.05}_{-0.07}$	$19.6^{+4.7}_{-1.3}$	$0.71^{+0.04}_{-0.04}$	400	$13.0^{+0.2}_{-0.4}$
GW190731_140936	$70.1^{+15.8}_{-11.3}$	$29.5^{+7.1}_{-5.2}$	$41.5^{+12.2}_{-9.0}$	$28.8^{+9.7}_{-9.5}$	$0.06^{+0.24}_{-0.24}$	$3.30^{+2.39}_{-1.72}$	$0.55^{+0.31}_{-0.26}$	$67.0^{+14.6}_{-10.8}$	$0.70^{+0.10}_{-0.13}$	3400	$8.7^{+0.2}_{-0.5}$
GW190803_022701	$64.5^{+12.6}_{-9.0}$	$27.3^{+5.7}_{-4.1}$	$37.3^{+10.6}_{-7.0}$	$27.3^{+7.8}_{-8.2}$	$-0.03^{+0.24}_{-0.27}$	$3.27^{+1.95}_{-1.58}$	$0.55^{+0.26}_{-0.24}$	$61.7^{+11.8}_{-8.5}$	$0.68^{+0.10}_{-0.11}$	1500	$8.6^{+0.3}_{-0.5}$
GW190814	$25.8^{+1.0}_{-0.9}$	$6.09^{+0.06}_{-0.06}$	$23.2^{+1.1}_{-1.0}$	$2.59^{+0.08}_{-0.09}$	$0.00^{+0.06}_{-0.06}$	$0.24^{+0.04}_{-0.05}$	$0.05^{+0.009}_{-0.010}$	$25.6^{+1.1}_{-0.9}$	$0.28^{+0.02}_{-0.02}$	19	$24.9^{+0.1}_{-0.2}$
GW190828_063405	$58.0^{+7.7}_{-4.8}$	$25.0^{+3.4}_{-2.1}$	$32.1^{+5.8}_{-4.0}$	$26.2^{+4.6}_{-4.8}$	$0.19^{+0.15}_{-0.16}$	$2.13^{+0.66}_{-0.93}$	$0.38^{+0.10}_{-0.15}$	$54.9^{+7.2}_{-4.3}$	$0.75^{+0.06}_{-0.07}$	520	$16.2^{+0.2}_{-0.3}$
GW190828_065509	$34.4^{+5.4}_{-4.4}$	$13.3^{+1.2}_{-1.0}$	$24.1^{+7.0}_{-7.2}$	$10.2^{+3.6}_{-2.1}$	$0.08^{+0.16}_{-0.16}$	$1.60^{+0.62}_{-0.60}$	$0.30^{+0.10}_{-0.10}$	$33.1^{+5.5}_{-4.5}$	$0.65^{+0.08}_{-0.08}$	660	$10.0^{+0.3}_{-0.5}$
GW190909_114149	$75.0^{+55.9}_{-17.6}$	$30.9^{+17.2}_{-7.5}$	$45.8^{+52.7}_{-13.3}$	$28.3^{+13.4}_{-12.7}$	$-0.06^{+0.37}_{-0.36}$	$3.77^{+3.27}_{-2.22}$	$0.62^{+0.41}_{-0.33}$	$72.0^{+54.9}_{-16.8}$	$0.66^{+0.15}_{-0.20}$	4700	$8.1^{+0.4}_{-0.6}$
GW190910_112807	$79.6^{+9.3}_{-9.1}$	$34.3^{+4.1}_{-4.1}$	$43.9^{+7.6}_{-6.1}$	$35.6^{+6.3}_{-7.2}$	$0.02^{+0.18}_{-0.18}$	$1.46^{+1.03}_{-0.58}$	$0.28^{+0.16}_{-0.10}$	$75.8^{+8.5}_{-8.6}$	$0.70^{+0.08}_{-0.07}$	11000	$14.1^{+0.2}_{-0.3}$
GW190915_235702	$59.9^{+7.5}_{-6.4}$	$25.3^{+3.2}_{-2.7}$	$35.3^{+9.5}_{-6.4}$	$24.4^{+5.6}_{-6.1}$	$0.02^{+0.20}_{-0.25}$	$1.62^{+0.71}_{-0.61}$	$0.30^{+0.11}_{-0.10}$	$57.2^{+7.1}_{-6.0}$	$0.70^{+0.09}_{-0.11}$	400	$13.6^{+0.2}_{-0.3}$
GW190924_021846	$13.9^{+5.1}_{-1.0}$	$5.8^{+0.2}_{-0.2}$	$8.9^{+7.0}_{-2.0}$	$5.0^{+1.4}_{-1.9}$	$0.03^{+0.30}_{-0.09}$	$0.57^{+0.22}_{-0.22}$	$0.12^{+0.04}_{-0.04}$	$13.3^{+5.2}_{-1.0}$	$0.67^{+0.05}_{-0.05}$	360	$11.5^{+0.3}_{-0.4}$
GW190929_012149	$104.3^{+34.9}_{-25.2}$	$35.8^{+14.9}_{-8.2}$	$80.8^{+33.0}_{-33.2}$	$24.1^{+19.3}_{-10.6}$	$0.01^{+0.34}_{-0.33}$	$2.13^{+3.65}_{-1.05}$	$0.38^{+0.49}_{-0.17}$	$101.5^{+33.6}_{-25.3}$	$0.66^{+0.20}_{-0.31}$	2200	$10.1^{+0.6}_{-0.8}$
GW190930_133541	$20.3^{+8.9}_{-1.5}$	$8.5^{+0.5}_{-0.5}$	$12.3^{+12.4}_{-2.3}$	$7.8^{+1.7}_{-3.3}$	$0.14^{+0.31}_{-0.15}$	$0.76^{+0.36}_{-0.32}$	$0.15^{+0.06}_{-0.06}$	$19.4^{+9.2}_{-1.5}$	$0.72^{+0.07}_{-0.06}$	1700	$9.5^{+0.3}_{-0.5}$

GW190814 – Loud event

- Detected online by Livingstone and Virgo, Hanford in commissioning mode, but undisturbed
  - Hanford data recovered offline
  - Best localised source (green skymap 23 deg^2)
  - The most mass asymmetric GW event detected

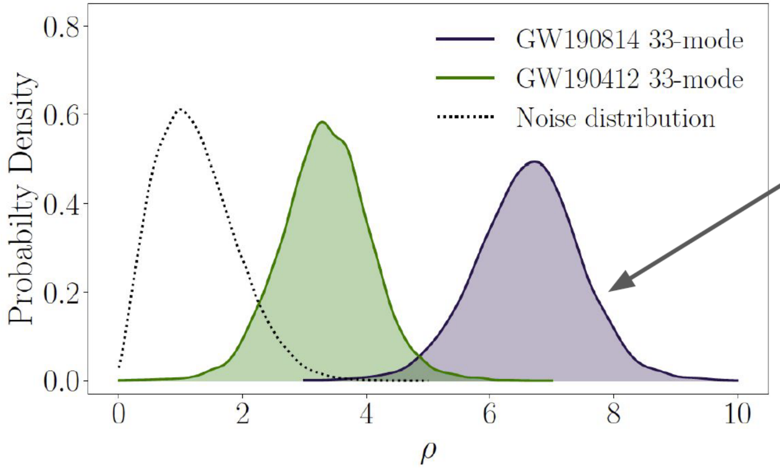






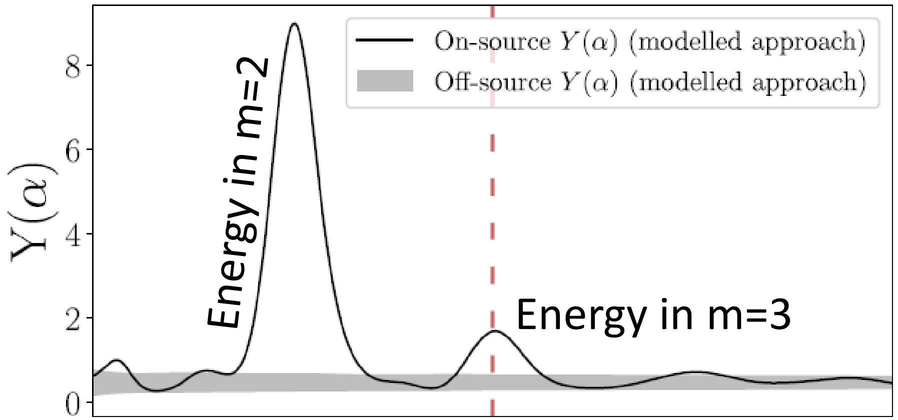
GW190814 – Higher order multipoles

- Being the mass distribution so asymmetric:

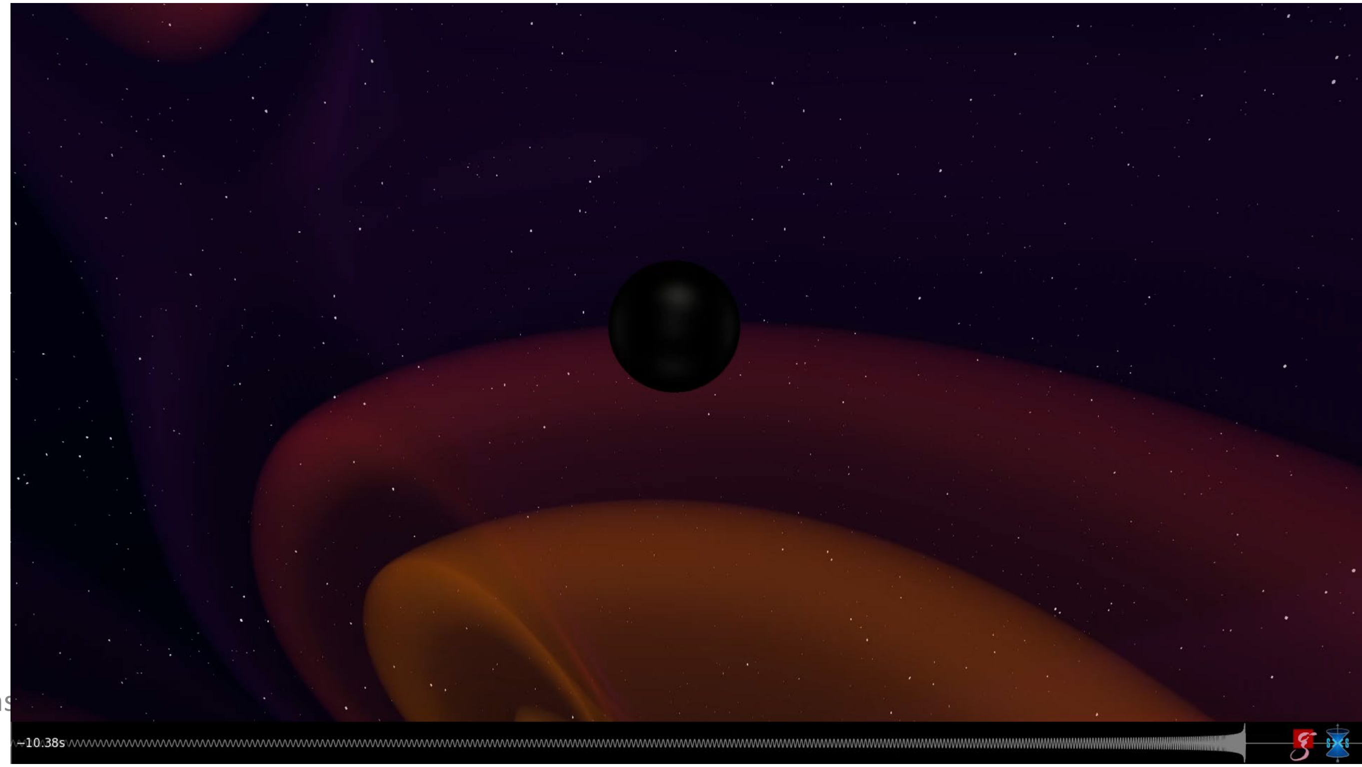


GW190814 has the strongest evidence for Higher order multiples that we have ever detected.

SNR in 33 multipole nearly as high as the total SNR of GW151012

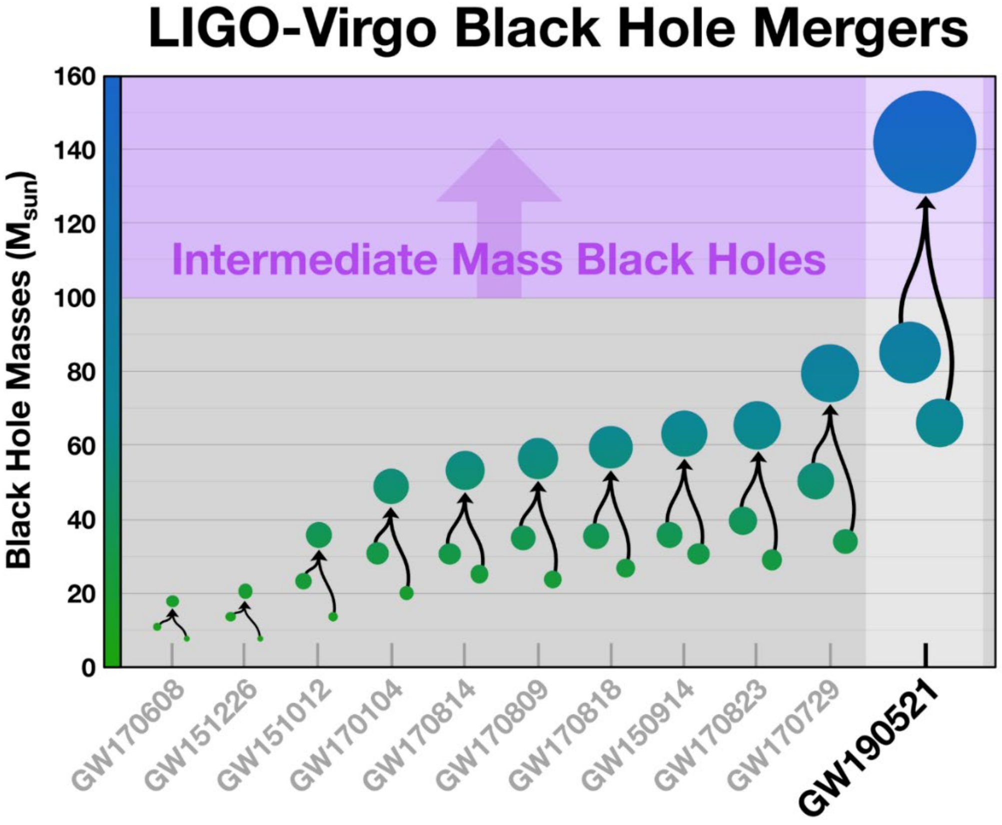


- Test of GR on strongly asymmetric mass distribution (GR “validated”)



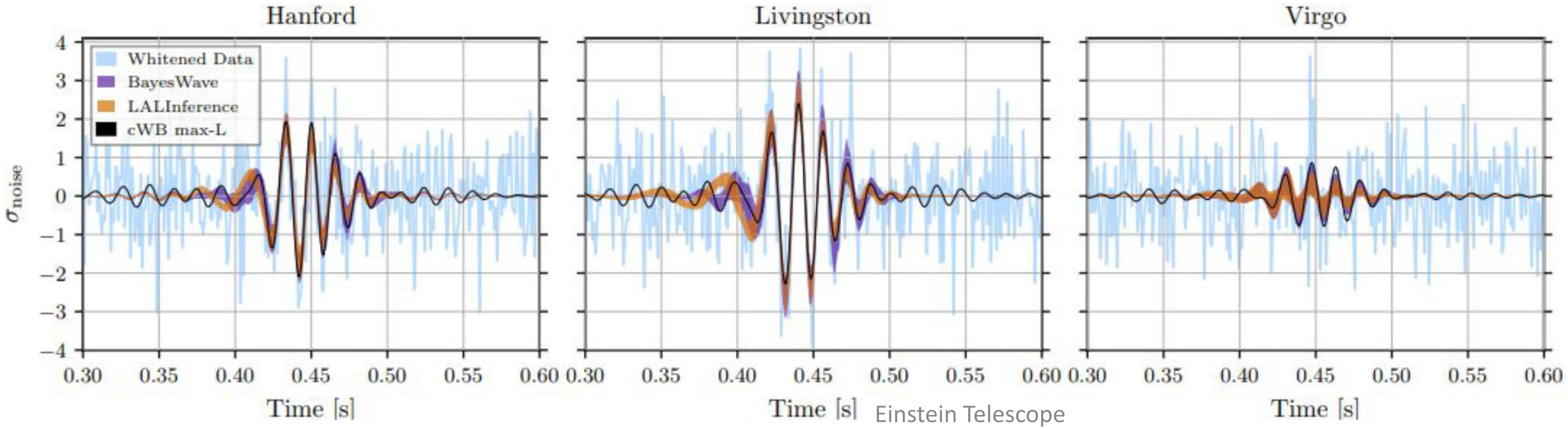
GW190521

$M_1 = 85^{+21}_{-14} M_\odot$, $M_2 = 66^{+17}_{-18} M_\odot$
at $z \sim 0.82$ (5.3Gpc)
Remnant $M_f = 142^{+28}_{-16} M_\odot$



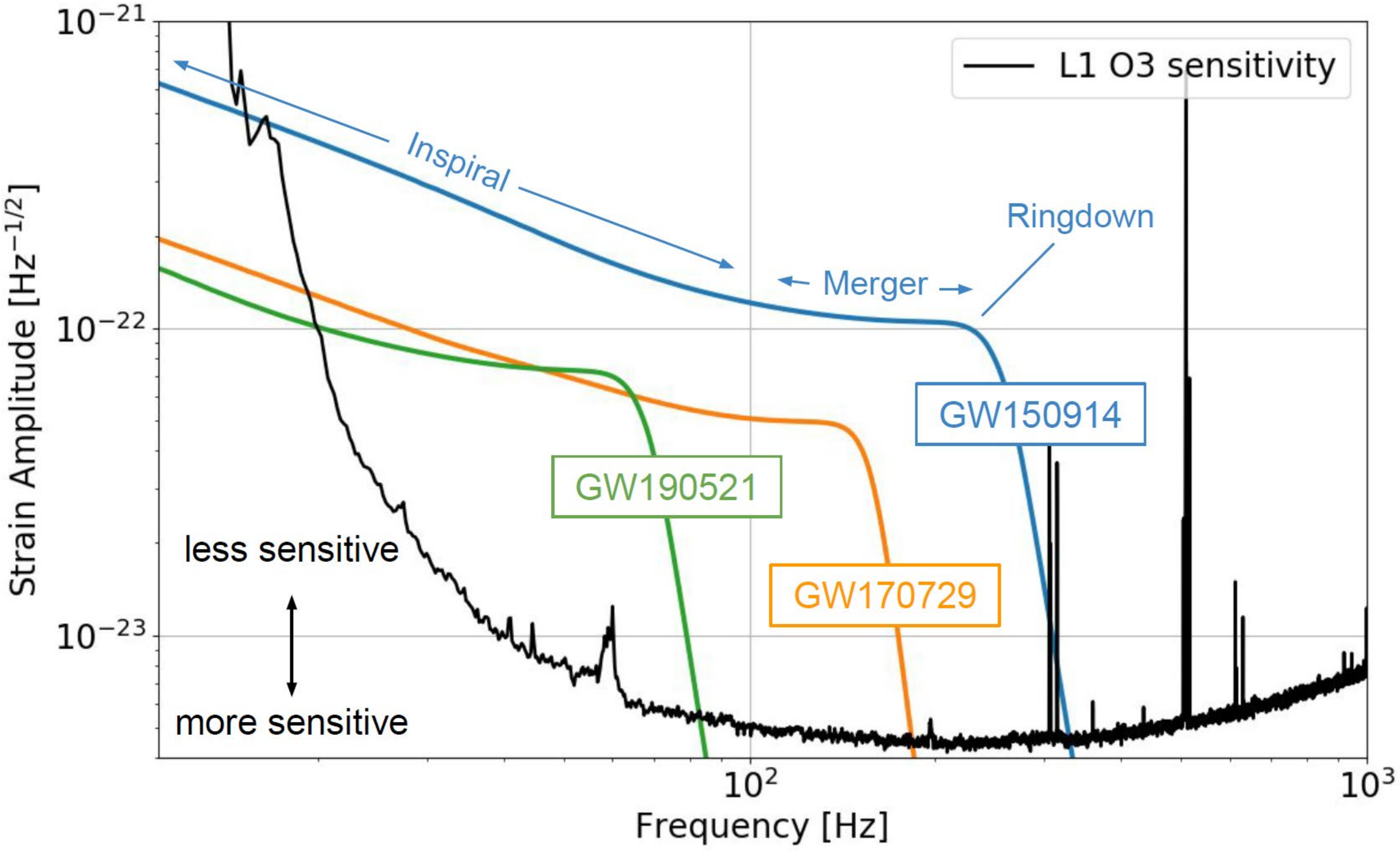
- Very special event:
  - M_1, the black hole that should not exist
  - M_f, the first IMBH ever seen

Phys. Rev. Lett. 125, 101102 (2020)
Astrophys. J. Lett. 900, L13 (2020)



Where is the chirp?

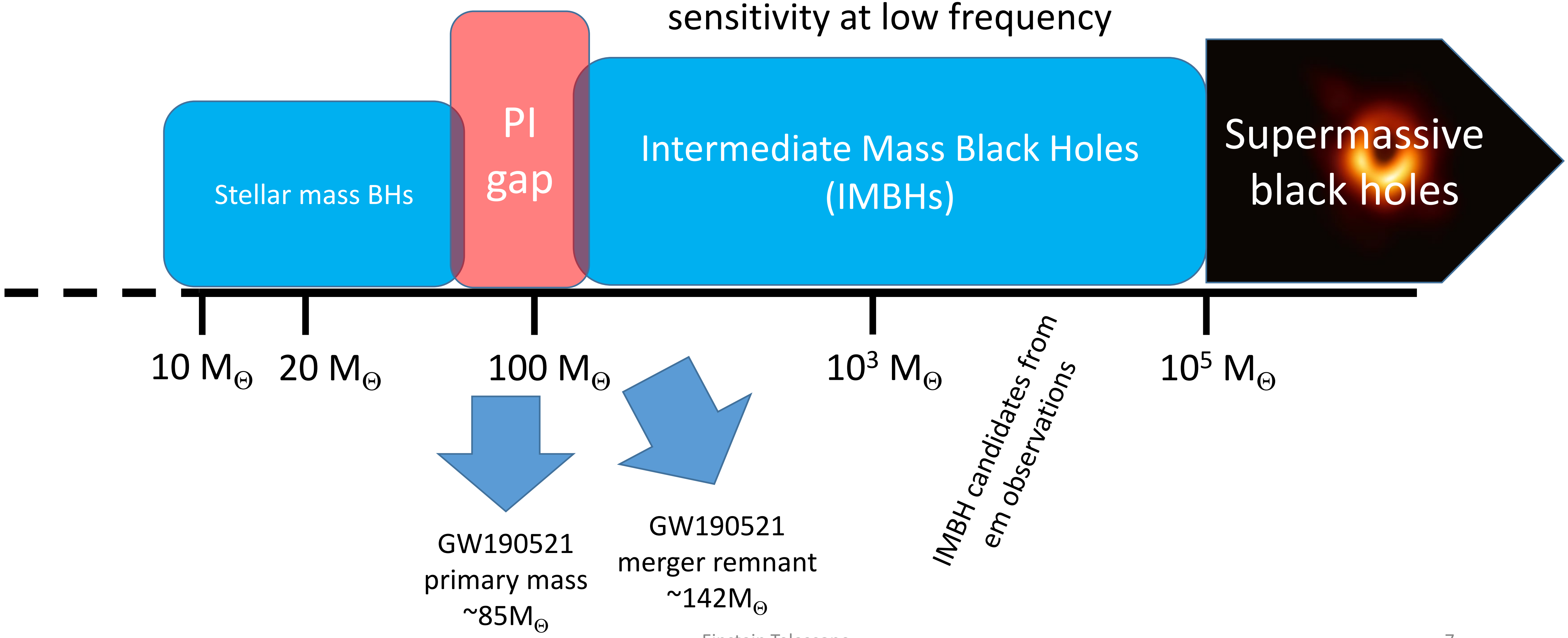
GW190521: LIGO-Virgo sensitivity to the BBH merger



- Higher masses correspond to lower frequency GW emission

BH masses

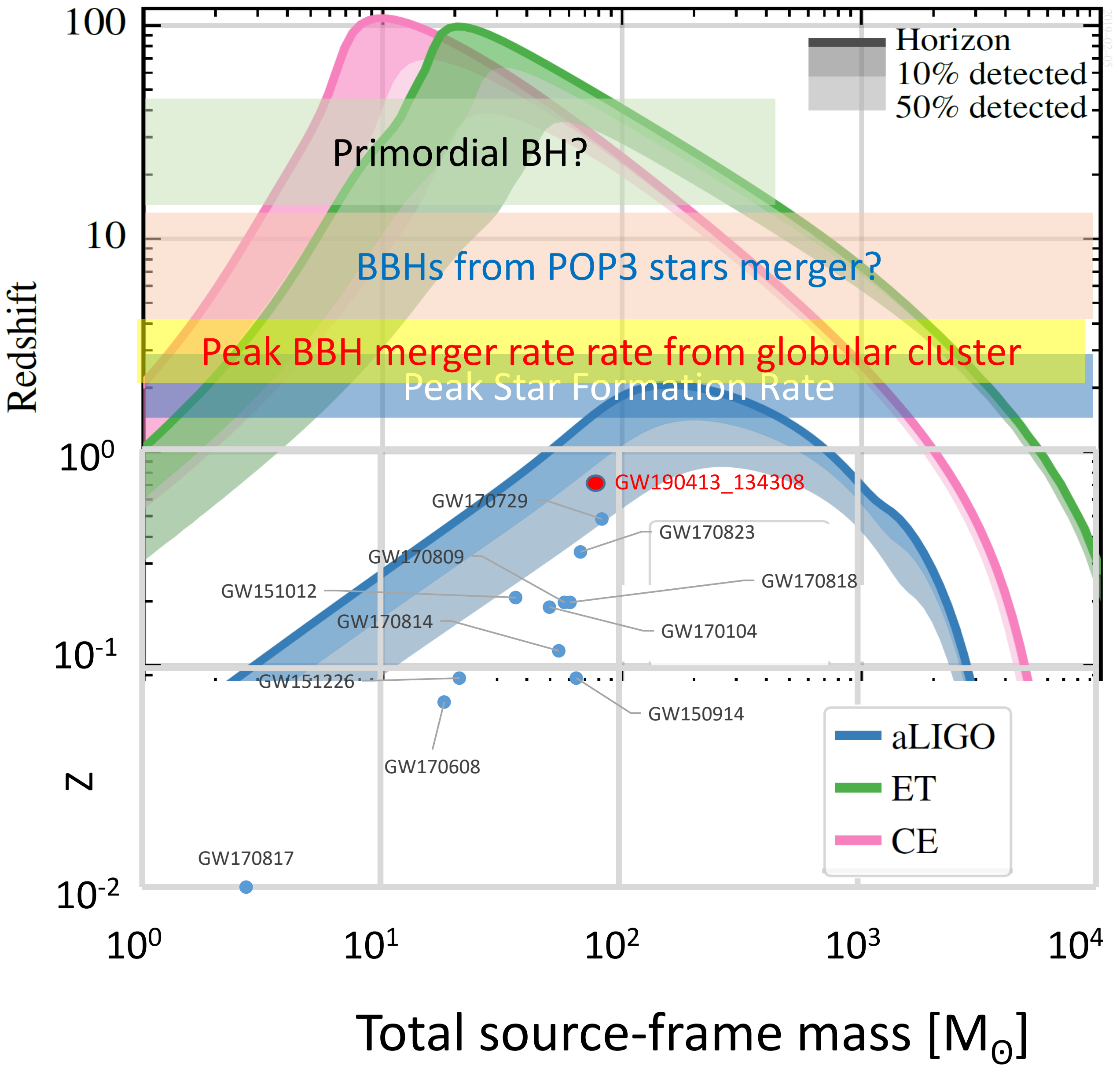
LIGO & Virgo will have marginal access to IMBH because of the "seismic wall" limiting the sensitivity at low frequency



OK, all done?

- aLIGO and AdV achieved awesome results with a reduced sensitivity
- When they will reach or over-perform their nominal sensitivity can we exploit all the potential of GW observations?

- 2nd generation GW detectors will explore local Universe, initiating the precision GW astronomy, but to have cosmological investigations a factor of 10 improvement in terms detection distance is needed



GWTC-1: A gravitational-wave transient catalog of compact binary mergers observed by LIGO and Virgo during the first and second observing runs - arXiv:1811.12907 [astro-ph.HE]

Detection distance of GWD

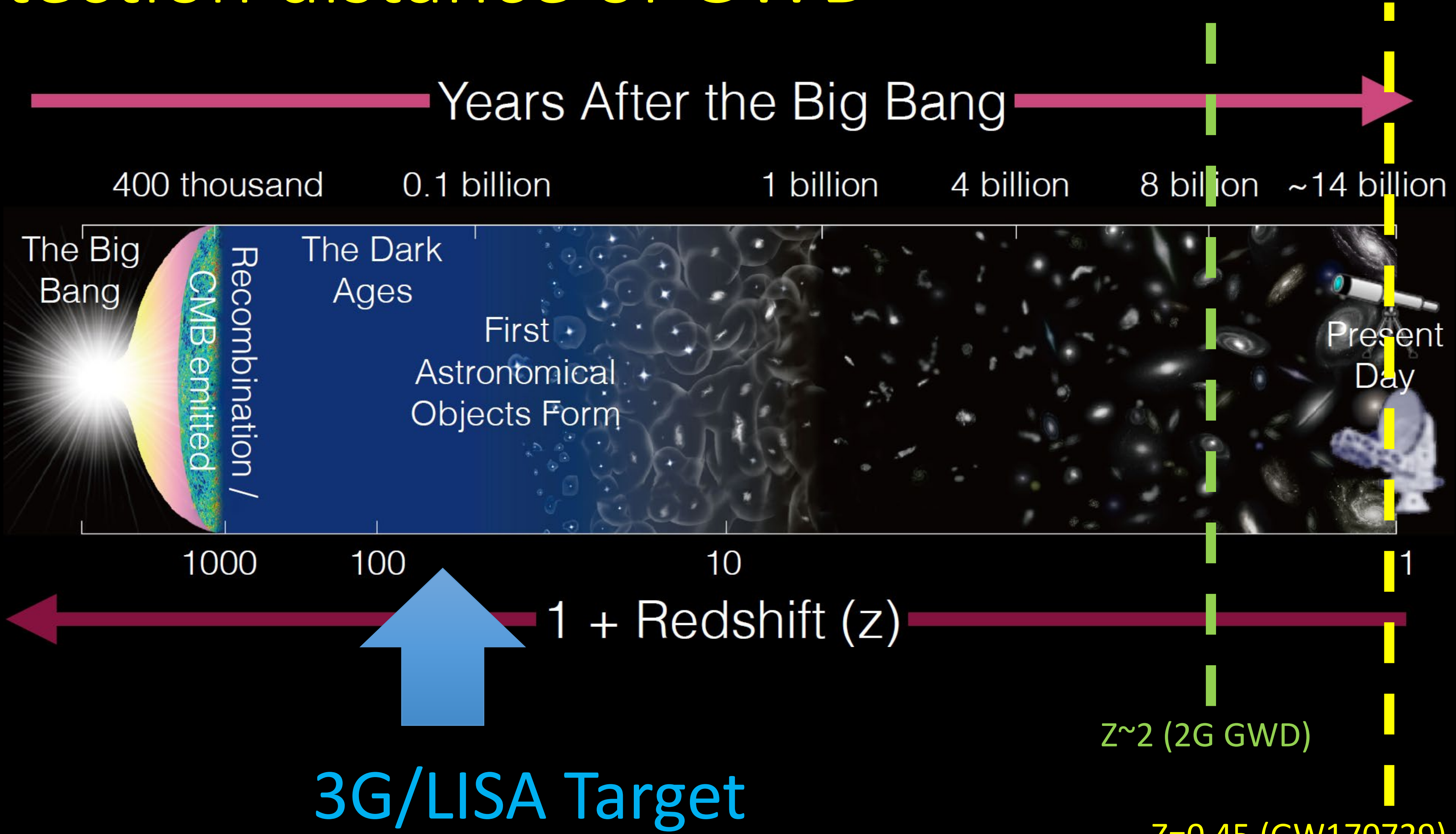
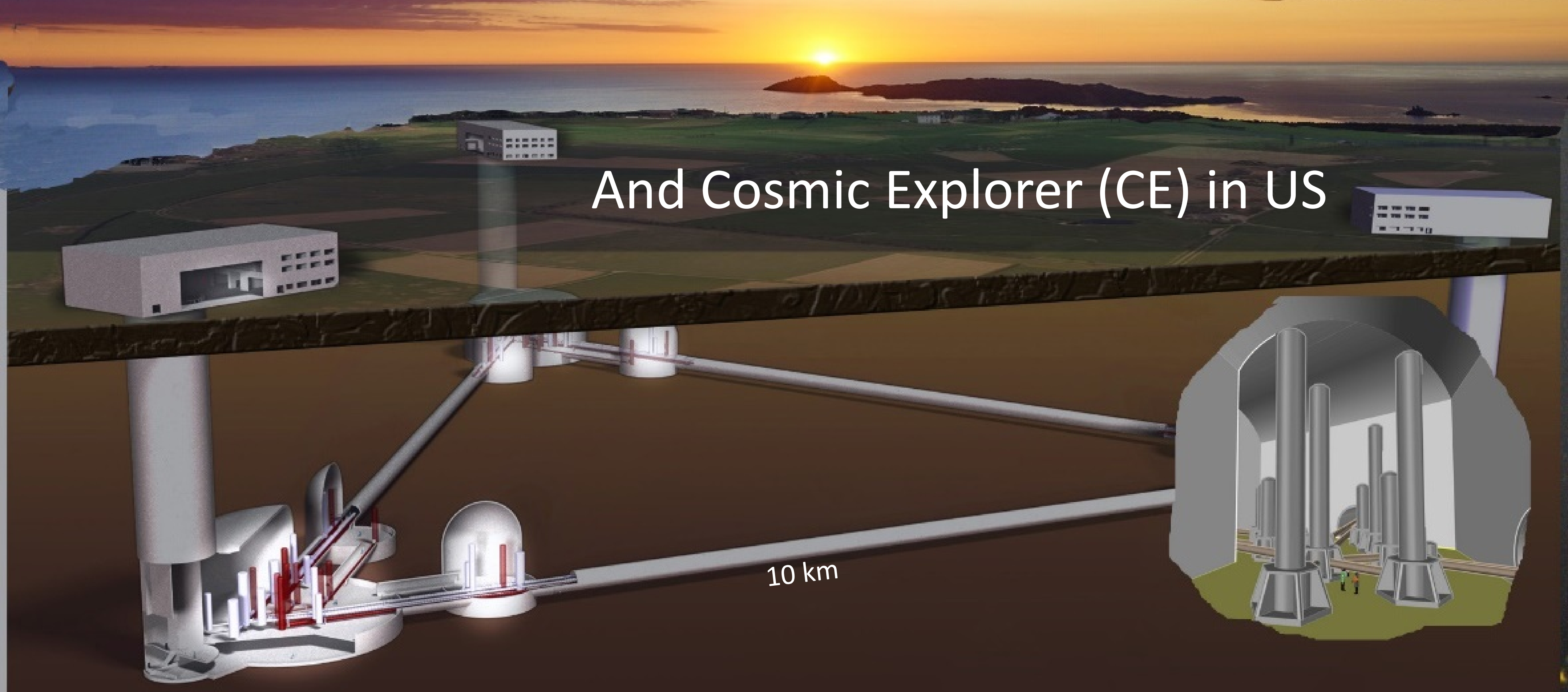


Image credit: NAOJ/ALMA http://alma.mtk.nao.ac.jp/

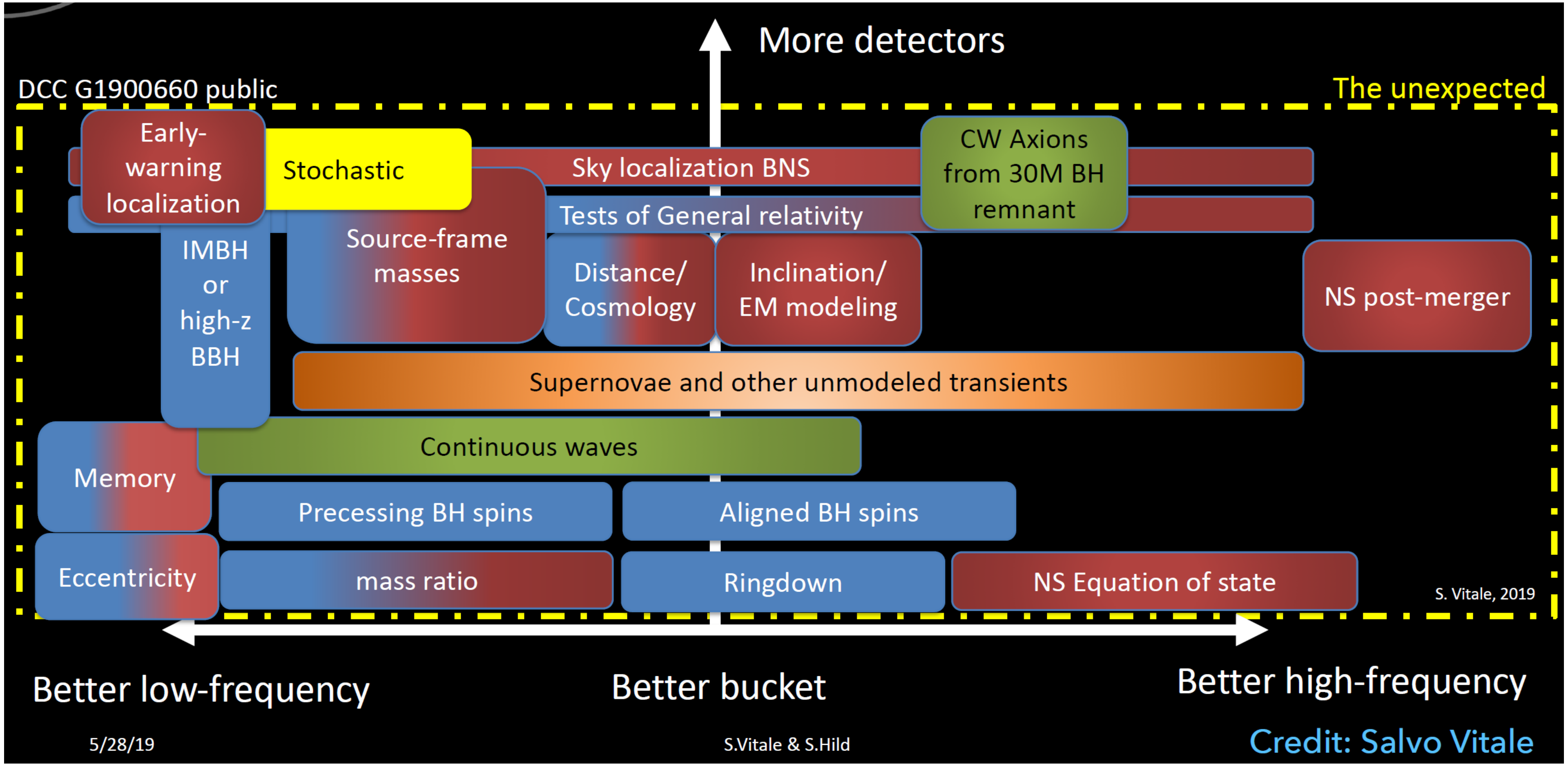
The Einstein Telescope

And Cosmic Explorer (CE) in US



Wideband or Narrow band?

- The design of the ET observatory is driven by the physics objectives
  - At what frequency are they?



Everywhere!

We need a wide band observatory

(with special attention to low frequency)

ET science targets

- A recent science case study for ET is here:
  - M.Maggiore et al, JCAP, 2020, 03, pp.050. ⟨10.1088/1475-7516/2020/03/050⟩
  - Hereafter a short list

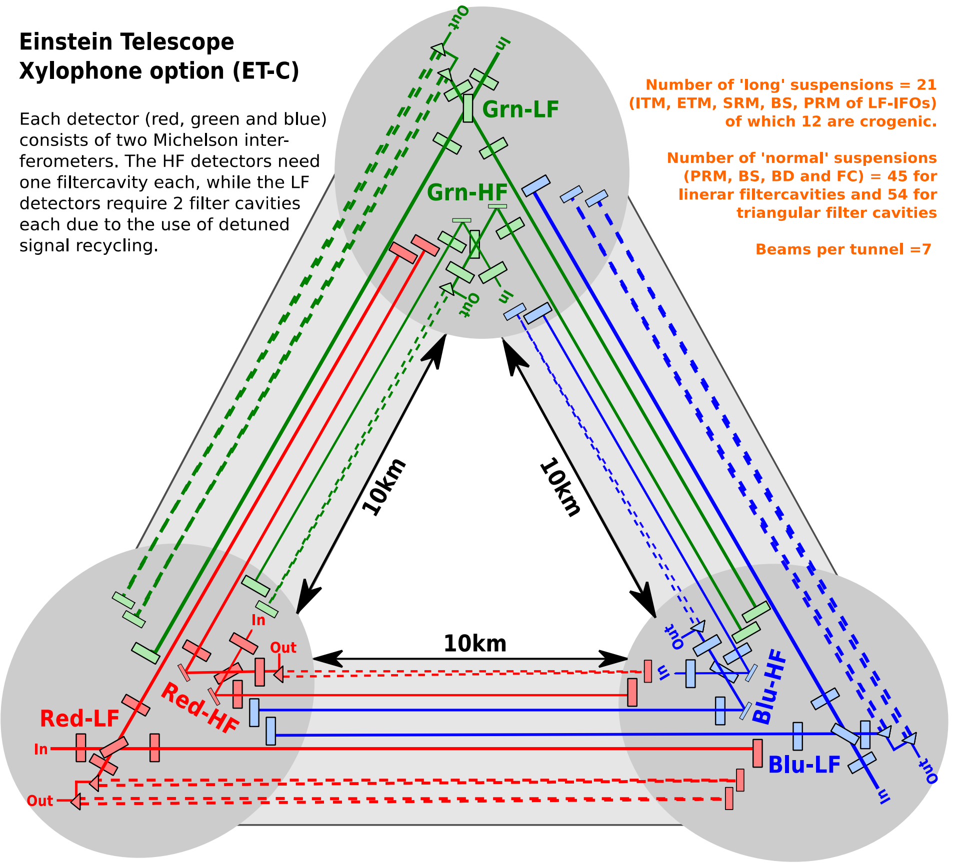
- Astrophysics
  - Black Hole physics
  - Neutron star physics
  - Multi-messenger astronomy
  - Core Collaps Sne
  - Isolated NS

- Fundamental physics
  - Testing GR
    - Perturbative regime
      - Inspiral phase of BH, post Newtonian expansion
    - Strong field regime
      - Physics near BH horizon
      - Exotic objects
  - QCD
    - NS interior structure
  - Dark matter
    - Primordial black holes
    - Axions
  - Dark Energy
    - DE equation of state
    - Modified propagation of GW

- The “Unexpected”
  - ???

ET Key ingredients

Factor 10 better sensitivity in a wide range of frequency
with a specific attention to low frequency (<10Hz)



- Einstein Telescope is a 3rd generation Gravitational Wave Observatory
  - It is, first of all, a new Research Infrastructure

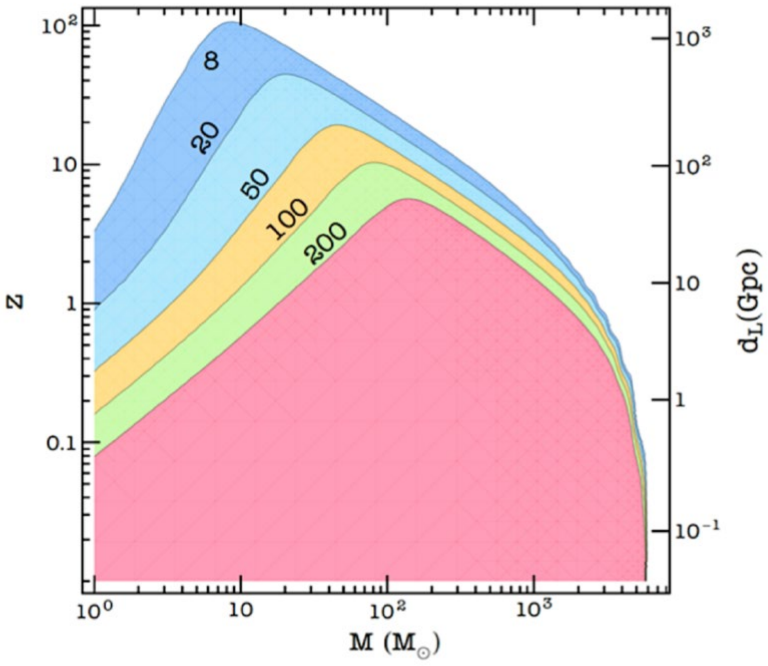
- Capable to host ET and its upgrades
- Capable to host 4G, 6G, …

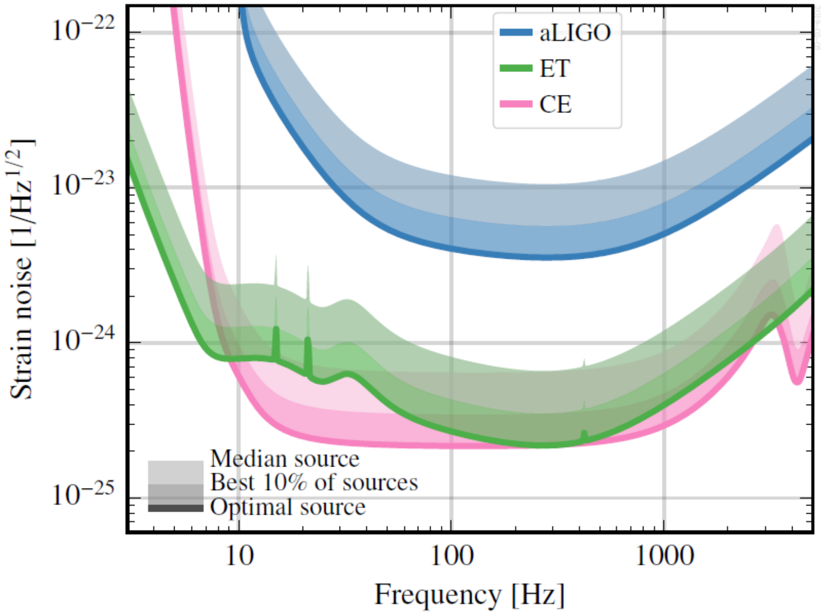
Observation (rather than detection) is the core business:

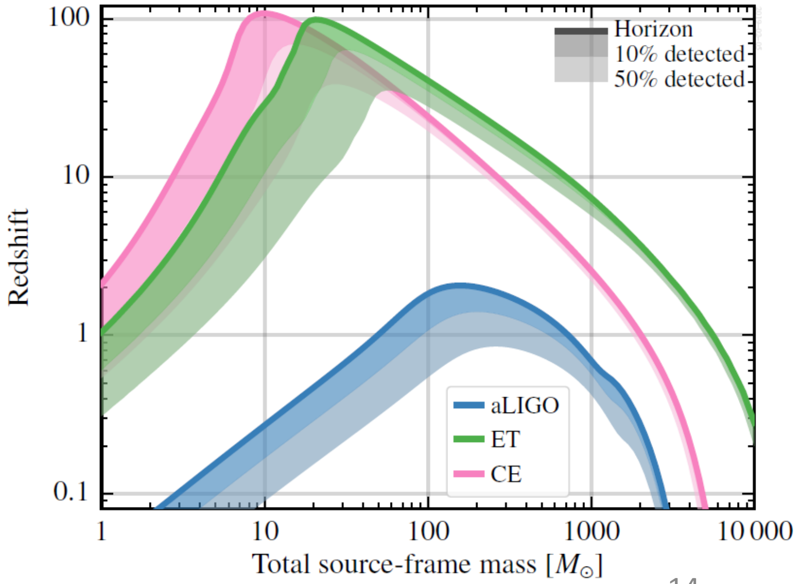
Requirements	Design Specifications
Wide frequency range	Xylophone (multi-interferometer) Design
Massive black holes (LF focus)	Underground
Localisation capability	Cryogenic
(more) Uniform sky coverage	Triangular shape
Polarisation disentanglement	Multi-detector design
High Reliability (high duty cycle)	Longer arms
High SNR	

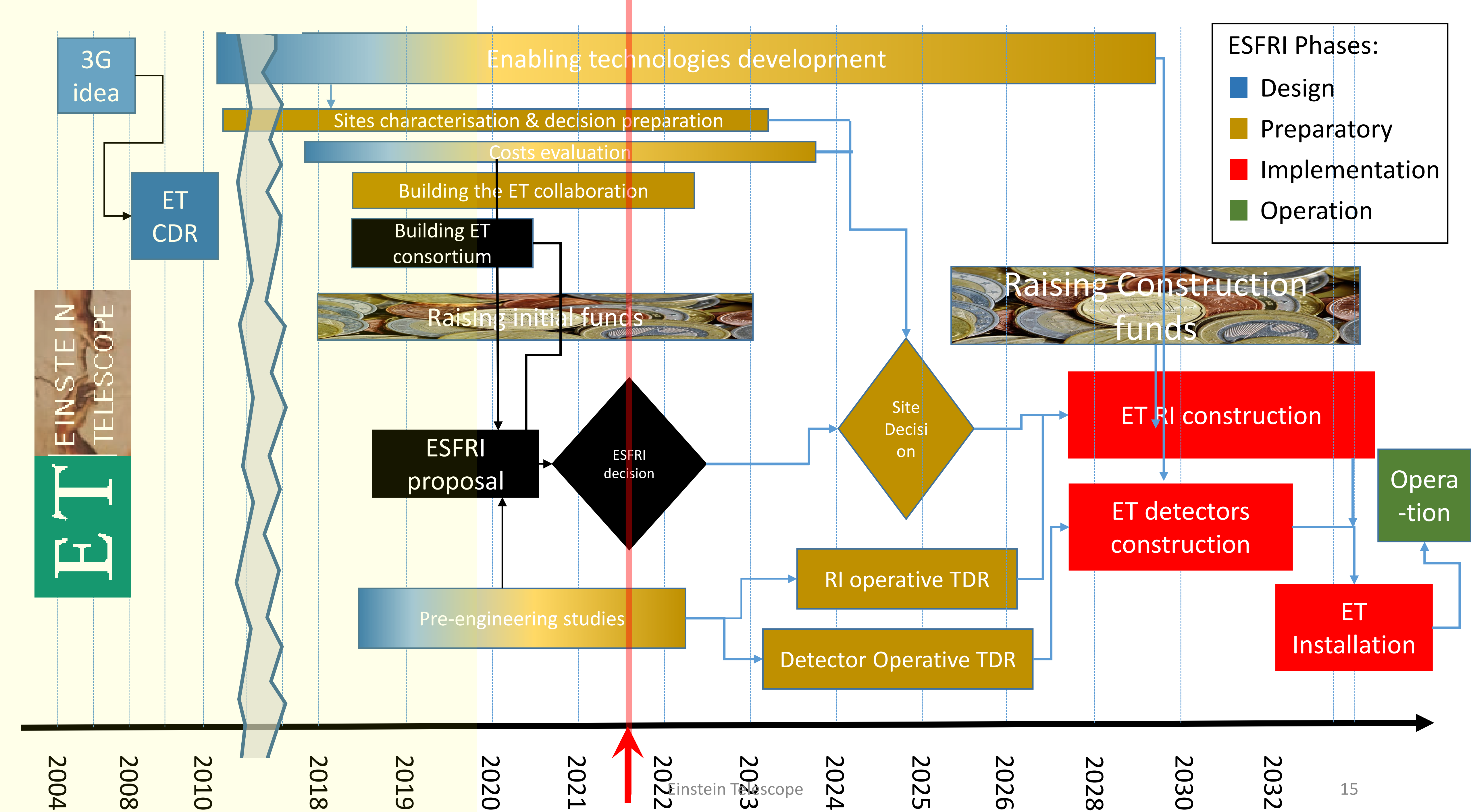
Key performances expected in ET

- BBH up to z~50
  - 10^6 BBH/year
  - Masses $M_T \gtrsim 10^3 M_\odot$
- BNS to z~2
  - 10^5 BNS/year
  - Possibly O(10-100)/year with e.m. counterpart
- High SNR








3G idea
ET CDR
Enabling technologies development
Sites characterisation & decision preparation
Costs evaluation
Building the ET collaboration
Building ET consortium
Raising initial funds
ESFRI proposal
ESFRI decision
Site Decision
Raising Construction funds
ET RI construction
ET detectors construction
RI operative TDR
Detector Operative TDR
Pre-engineering studies
ET Installation
Opera-tion
ESFRI Phases:
Design
Preparatory
Implementation
Operation
EINSTEIN TELESCOPE
ET
2004
2008
2010
2018
2019
2020
2021
2022
2023
2024
2025
2026
2028
2030
2032

European Strategy Forum on Research Infrastructures

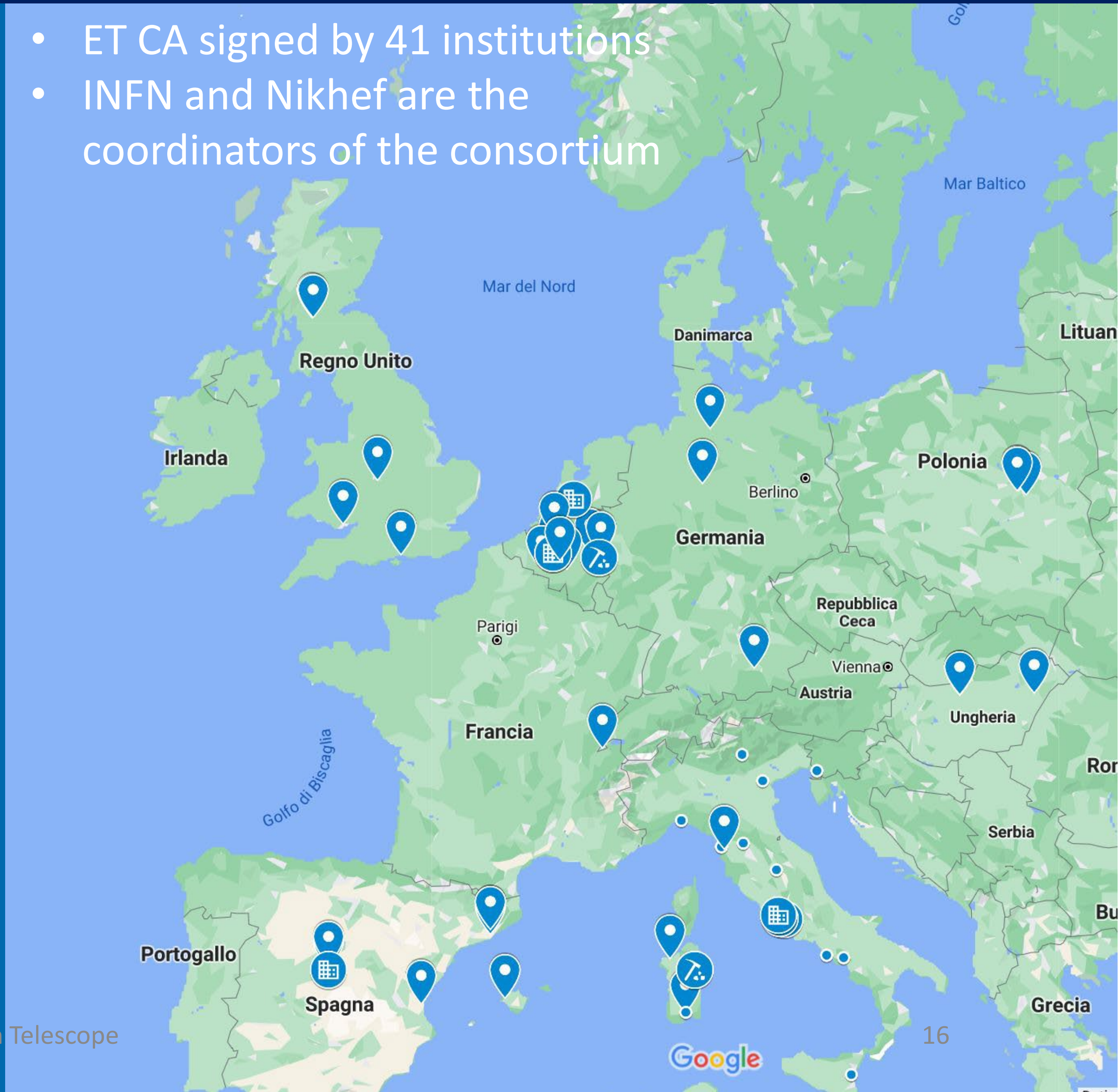
ESFRI Roadmap

ET EINSTEIN TELESCOPE

Proposal submitted by:

- **Italy** (Lead Country)
- Netherlands
- Belgium
- Spain
- Poland

- ET CA signed by 41 institutions
- INFN and Nikhef are the coordinators of the consortium



30/06/2021: ET enters in the ESFRI roadmap

01 LUGLIO 2021

ET ED EUPRAXIA CON L'ITALIA CAPOFILA ENTRANO NELLA ROADMAP DI ESFRI

ET Einstein Telescope ed EuPRAXIA: due grandi infrastrutture di ricerca competitive a livello mondiale, rispettivamente nella ricerca sulle onde gravitazionali e nello sviluppo di futuri acceleratori di particelle al plasma. Sono questi i due progetti internazionali di cui l'INFN Istituto Nazionale di Fisica Nucleare è capofila, e che l'Italia attraverso il MUR Ministero dell'Università e della Ricerca ha candidato lo scorso settembre per la Roadmap 2021 di ESFRI European Strategy Forum on Research Infrastructure, il forum strategico europeo che individua le grandi infrastrutture di ricerca su cui investire a livello europeo. Dopo un lungo e accurato processo di valutazione dei progetti candidati, il 30 giugno, l'Assemblea di ESFRI ha approvato entrambi, ET ed EuPRAXIA, che entrano così nel novero delle grandi infrastrutture di ricerca su cui l'Europa punterà nel prossimo futuro.

"L'inclusione di ET ed EuPRAXIA nella Roadmap di ESFRI è un importante risultato che ne rafforza il valore strategico a livello europeo", commenta **Antonio Zoccoli, presidente dell'INFN**. "Le grandi infrastrutture di ricerca sono una risorsa per la scienza e la conoscenza, ma anche per lo sviluppo industriale, l'innovazione tecnologica, la crescita economica, culturale e sociale. Forti della leadership scientifica del nostro Paese a livello internazionale, metteremo il massimo impegno per il loro sviluppo, e per valorizzare la candidatura del sito italiano a ospitare ET, e siamo certi che con il sostegno del MUR, della Regione Sardegna, delle Istituzioni nazionali e locali, abbiamo ottime possibilità di raggiungere l'obiettivo, a beneficio del territorio e del Paese".

Nikhef Menu Search

Einstein Telescope approved for ESFRI Roadmap 2021

1 July 2021

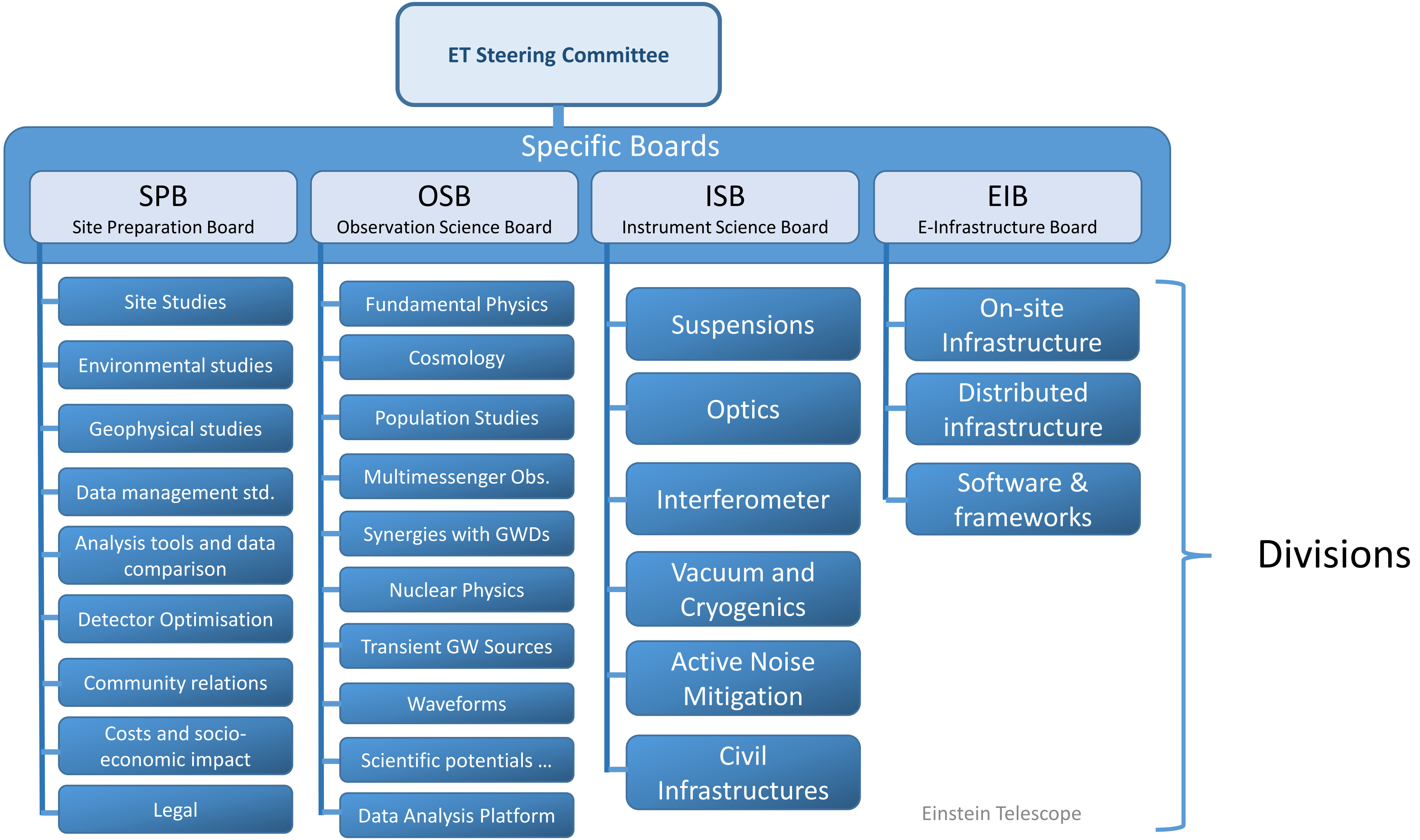
On June 30th, the European Strategy Forum on Research Infrastructures (ESFRI) decided to include the Einstein Telescope in the 2021 upgrade of its roadmap. This confirms the relevance of this major international project for a next generation gravitational waves observatory for the future of research infrastructures in Europe and gravitational wave research at a global level.

30/06/2021: ET enters in the ESFRI roadmap

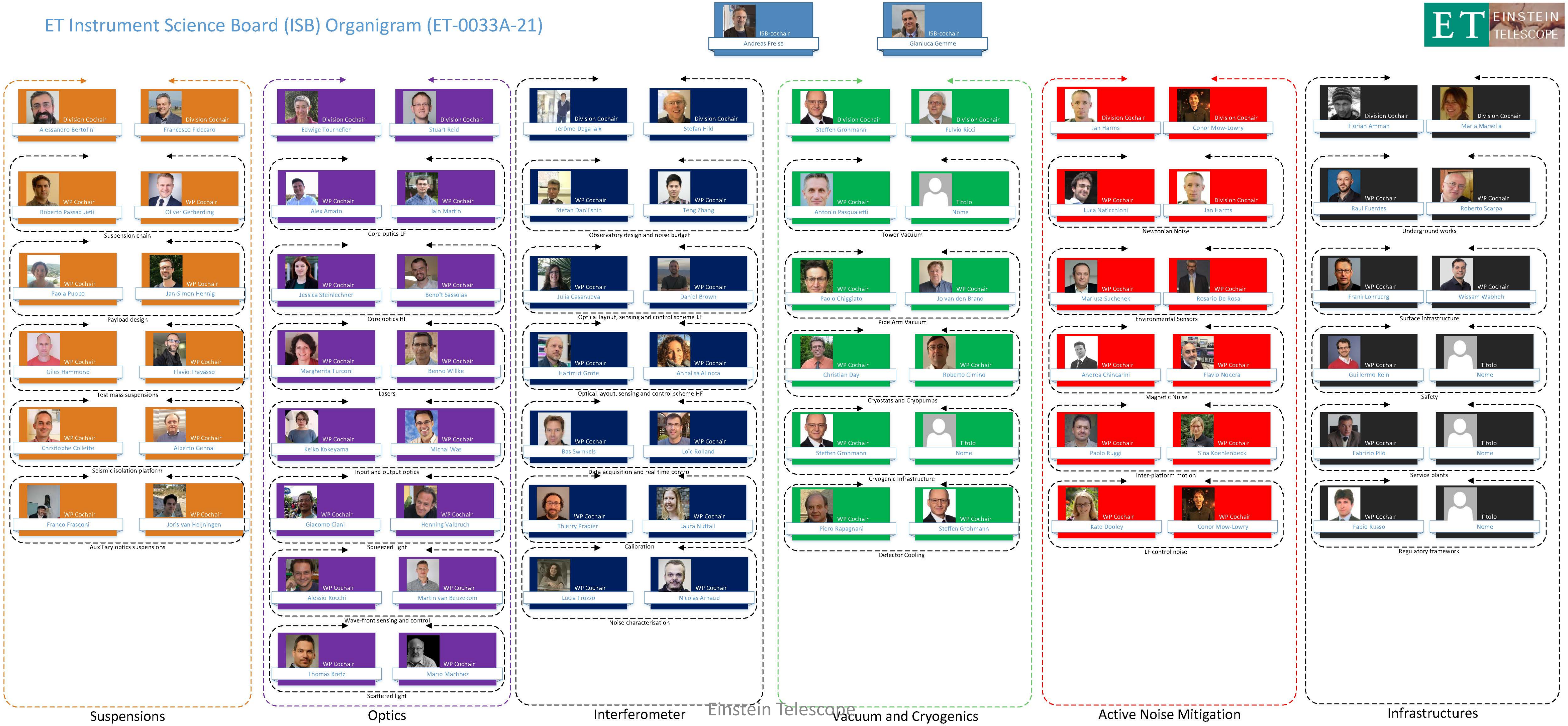
- Why it is so important for ET to be in the ESFRI roadmap?
  - ESFRI has not funds
  - But to be in the ESFRI roadmap
    - Is a quality stamp that certifies the readiness level of the project: it states the passage from the design phase to the preparatory phase
    - Allows to access a (small) financial support from the European Commission for the preparatory phase
    - Allows to access specific (and potentially large) national and regional funds in Europe
    - Facilitates the coordination of different European countries at government level targeting the realisation of the infrastructure

ET organisation

ET collaboration current organisation



ISB: Instrument Science Board

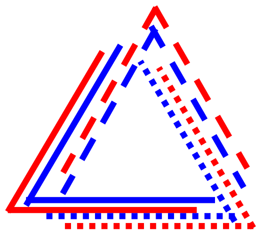


ESFRI

Q1: Enabling Technologies

ET EINSTEIN TELESCOPE

- The multi-interferometer approach asks for two parallel technology developments:



- **ET-LF:**
  - Underground
  - Cryogenics
  - Silicon (Sapphire) test masses
  - Large test masses
  - New coatings
  - New laser wavelength
  - Seismic suspensions
  - Frequency dependent squeezing

- **ET-HF:**
  - High power laser
  - Large test masses
  - New coatings
  - Thermal compensation
  - Frequency dependent squeezing

Challenging engineering

New technology in cryo-cooling

New technology in optics

New laser technology

High precision mechanics and low noise controls

High quality opto-electronics and new controls

Evolved laser technology

Evolved technology in optics

Highly innovative adaptive optics

High quality opto-electronics and new controls

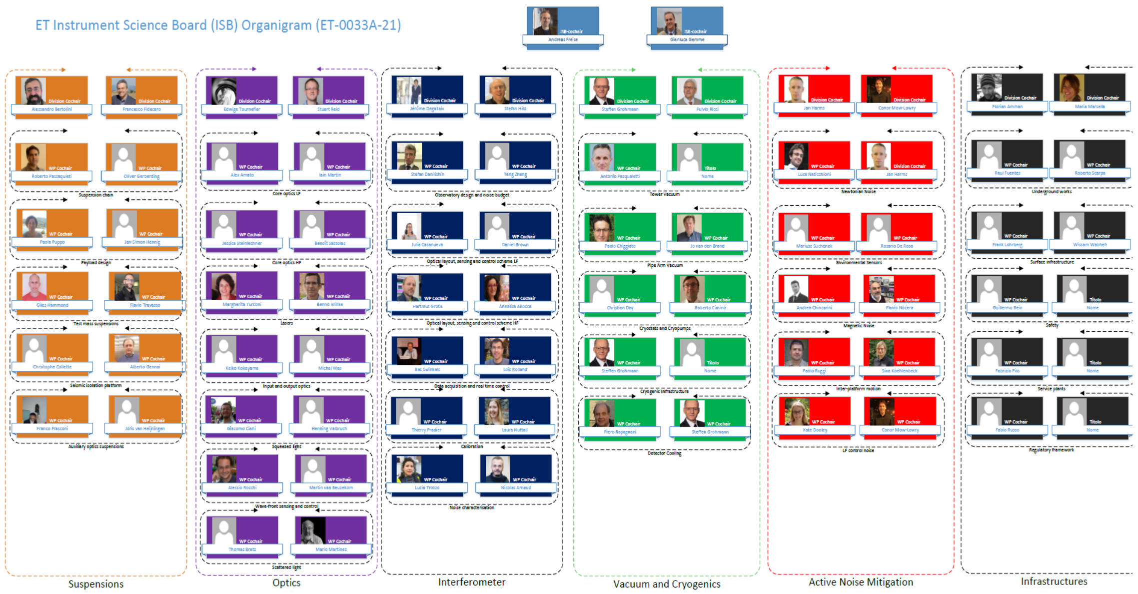
OSB: Observational Science Board

Marica Branchesi - Michele Maggiore - Ed Porter

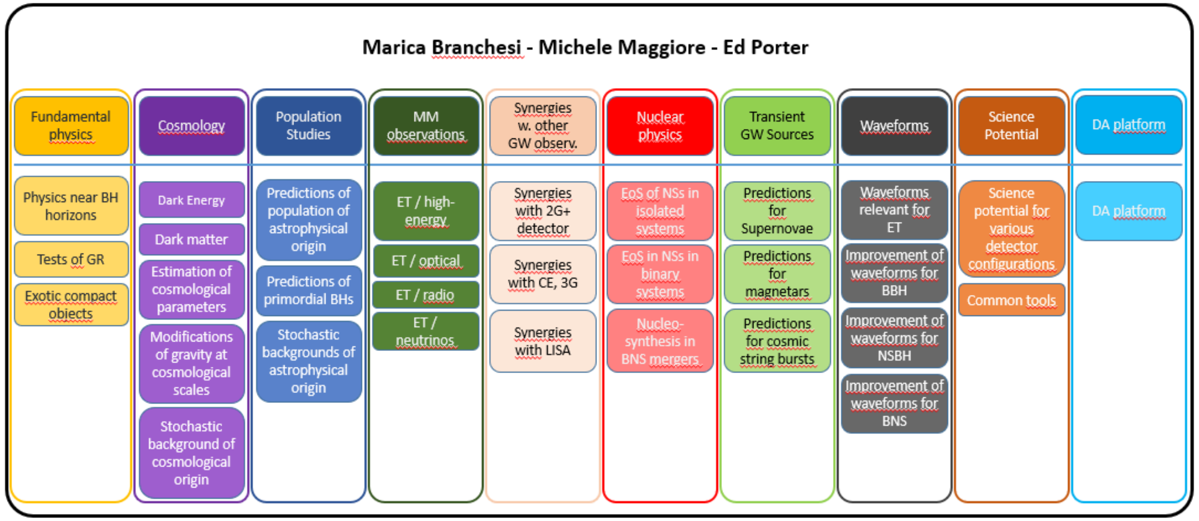
Kick-off workshop end of September 2021

- **Fundamental physics**
  - Physics near BH horizons
  - Tests of GR
  - Exotic compact objects
- **Cosmology**
  - Dark Energy
  - Dark matter
  - Estimation of cosmological parameters
  - Modifications of gravity at cosmological scales
  - Stochastic background of cosmological origin
- **Population Studies**
  - Predictions of population of astrophysical origin
  - Predictions of primordial BHs
  - Stochastic backgrounds of astrophysical origin
- **MM observations**
  - ET / high-energy
  - ET / optical
  - ET / radio
  - ET / neutrinos
- **Synergies w. other GW observ.**
  - Synergies with 2G+ detector
  - Synergies with CE, 3G
  - Synergies with LISA
- **Nuclear physics**
  - EoS of NSs in isolated systems
  - EoS of NSs in binary systems
  - Nucleo-synthesis in BNS mergers
- **Transient GW Sources**
  - Predictions for supernovae
  - Predictions for magnetars
  - Predictions for cosmic string bursts
- **Waveforms**
  - Waveforms relevant for ET
  - Improvement of waveforms for BBH
  - Improvement of waveforms for NSBH
  - Improvement of waveforms for BNS
- **Science Potential**
  - Science potential for various detector configurations
  - Common tools
- **DA platform**
  - DA platform

Instrument Science Board



Observational Science



How to join?

If you are interested in contributing, please get in touch with one of the division or working group chairs

Check out the ISB webpage: https://wiki.et-gw.eu/ISB/WelcomePage

The Instrument Science Board (ISB) is described in more detail in:
https://apps.et-gw.eu/tds/ql/?c=15709
https://apps.et-gw.eu/tds/ql/?c=15707

ET-0000A-19
KAGRA-M1909820

Letter of Intent

on the scientific collaboration between

the Einstein Telescope collaboration

and

the KAGRA collaboration

This letter outlines the intent of the two parties, the Einstein Telescope collaboration (ET collaboration, hereafter) and the KAGRA collaboration, to collaborate in the development of the technologies needed to upgrade the current detectors and to realise the 3rd generation of gravitational wave (GW) observatories such as ET.

Evolution of the ET collaboration

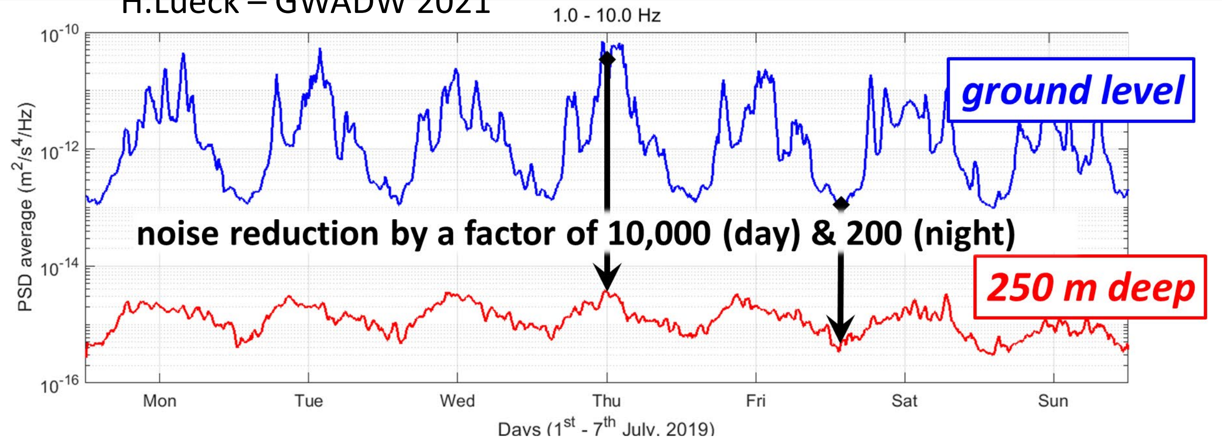
- After the ESFRI announce, the process to realise the ET collaboration is speeding up.
- The ET steering committee will evolve toward a more complex structure having an operative bodies (executive board, …) and representative bodies (Collaboration board, …)
- The relationship with the “project” component are going to be defined
- Target: Fall 2021

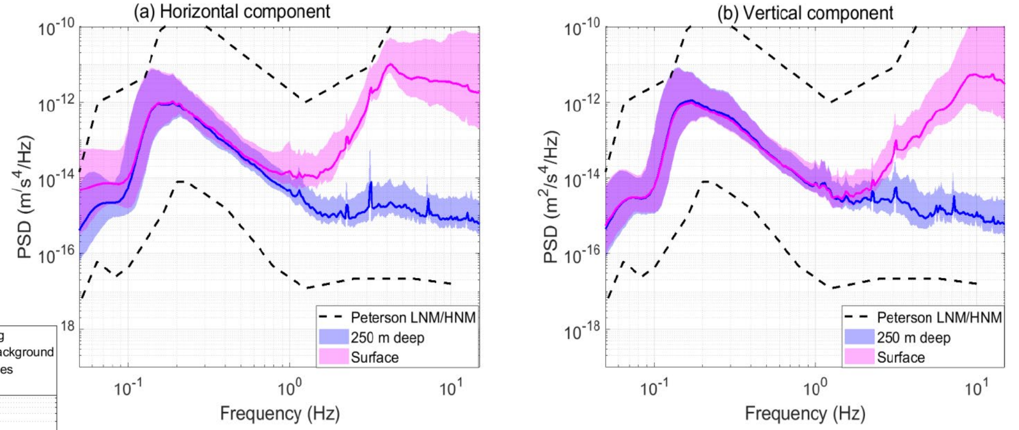
SPB: ET sites under characterisation

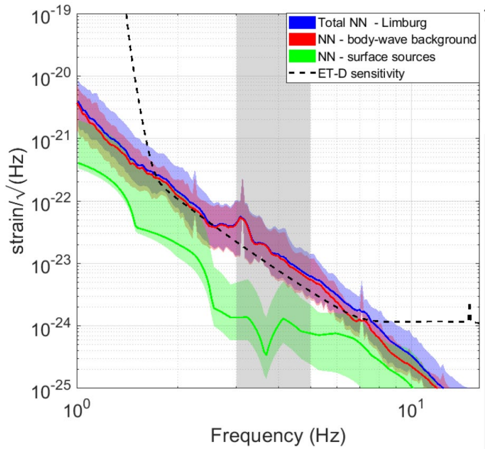
Euregio Meuse-Rhine

- A 250-m deep borehole has been excavated and equipped
  - Seismic data under acquisition and analysis
- 3-5 other boreholes expected
- Extensive active and passive site characterisation with sensor arrays in 2021
- Good seismic noise attenuation given by the particular geological structure
- ET pathfinder centre under construction
- 15+15M€ funding through Interreg grants

H.Lueck – GWADW 2021







Soumen Koley, GWADW 2021

SPB: ET sites under characterisation

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Euregio Meuse-Rhine

- A 250-m deep borehole has been excavated and equipped
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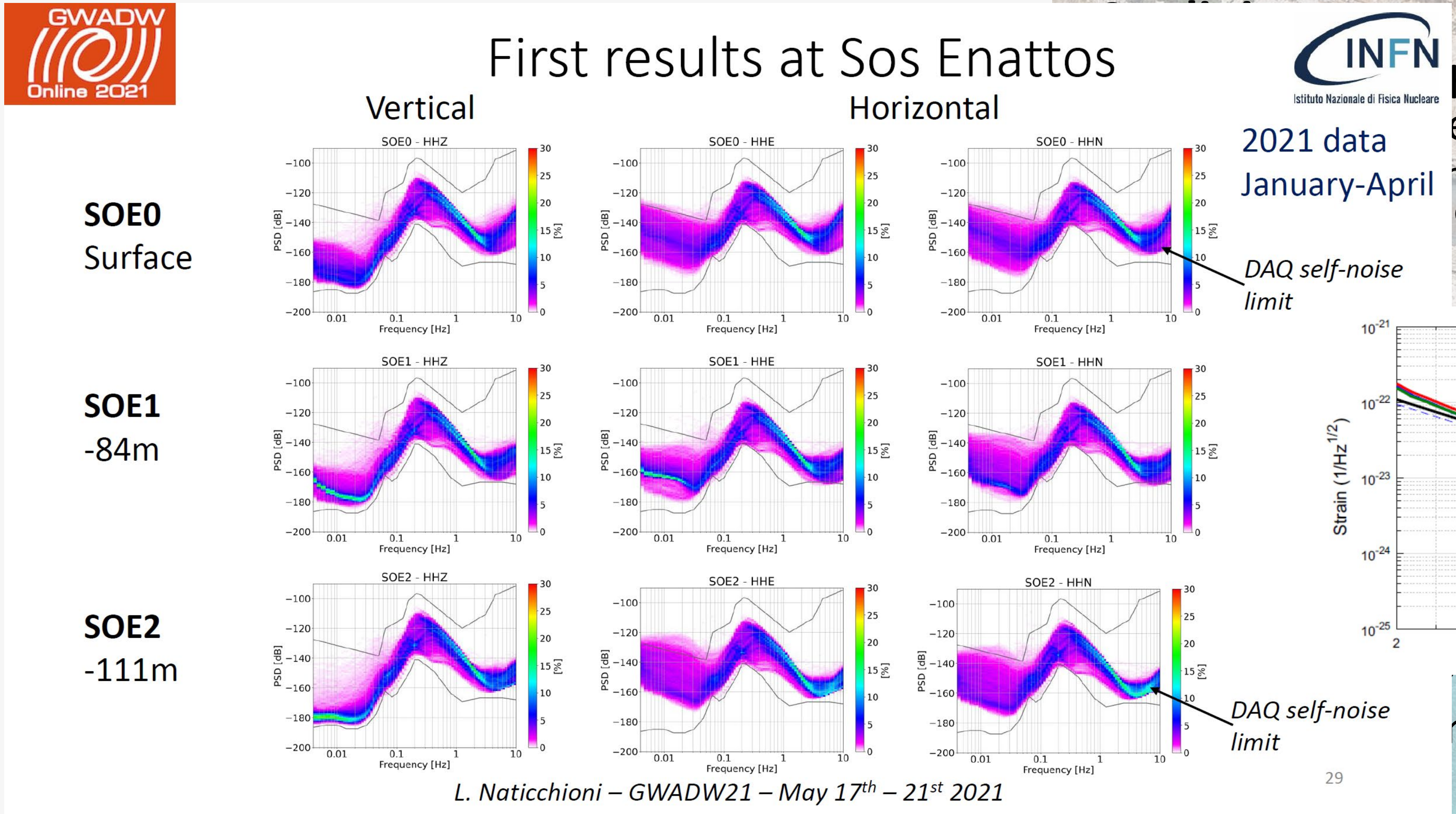
- 3-5 other boreholes expected
- Extensive active and passive site characterisation with sensor arrays in 2021
- Good seismic noise attenuation given by the particular geological structure
- ET pathfinder centre under construction
- 15+15M€ funding through Interreg grants

Sardinia

- Long standing characterisation of the mine in one of the corners continuing
  - Seismic, magnetic and acoustic noise characterisation ongoing at different depth in the mine
- Underground laboratory under construction (SarGrav)
- A 290m borehole has been excavated and it will be equipped
- A second borehole to be excavated in the summer 2021
- Intense & international surface investigations programme in Summer 2021
- 17+3.5+1+11M€ funding through national and regional funds

SPB: ET sites under characterisation



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…ers continuing
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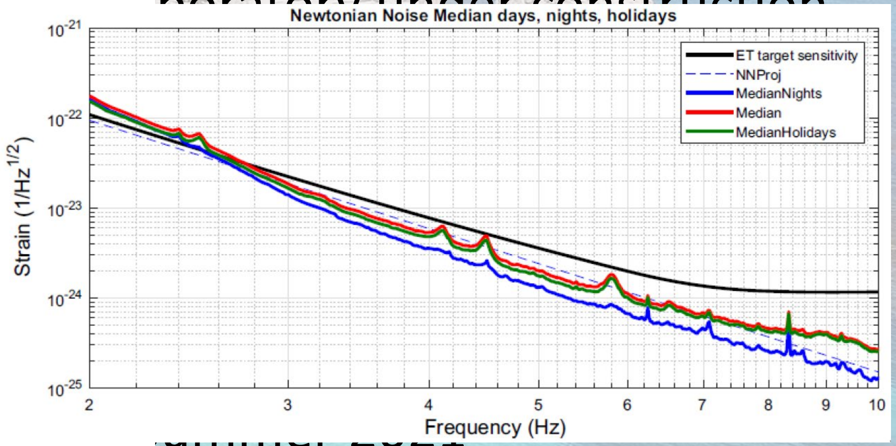
…on ongoing at different depth in

…boratory under construction

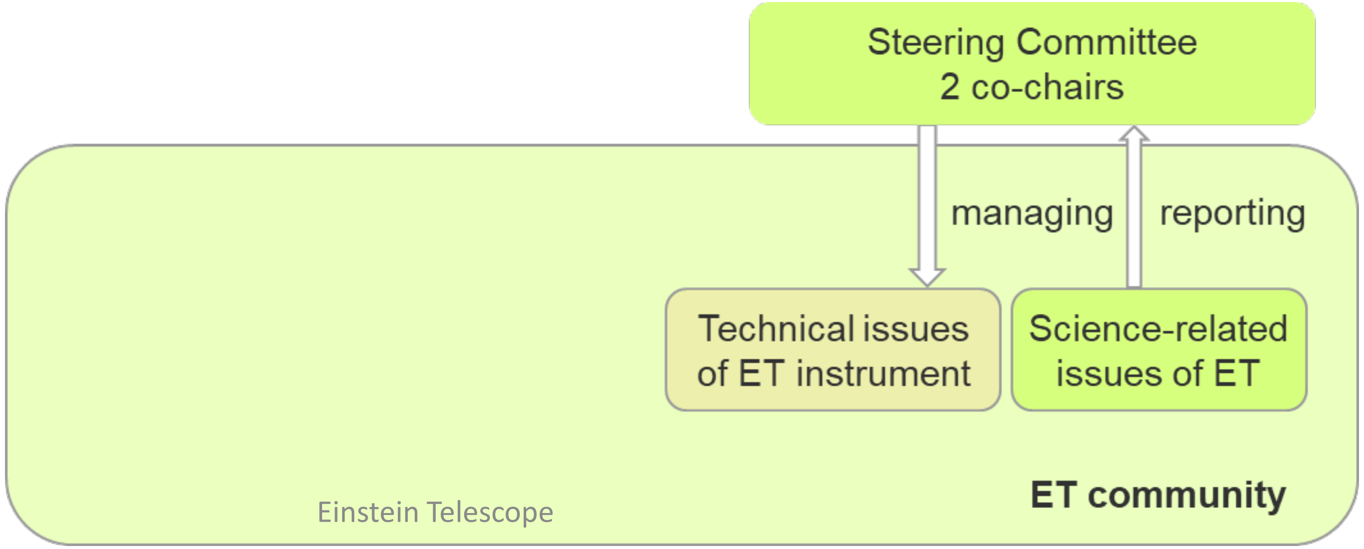


…ummer 2021
…nding through national and

-L.Naticchioni e tal.,***Characterization of the Sos Enattos site for the Einstein Telescope***,**JPCS**1468,2020
-M.DiGiovanni et al.,***A seismological study of the Sos Enattos Area–the Sardinia Candidate Site for the Einstein Telescope***, **SRL**,2020https://doi.org/10.1785/0220200186
-A.Allocca et al.,***Seismic glitchness at Sos Enattos site: impact on intermediate black hole binaries detection efficiency***, **EPJP**,2021https://doi.org/10.1140/epjp/s13360-021-01450-8

ET Structure - 2020

- **Until now: A broad ET scientific community;**



Governance proposal for the Preparation phase

ESFRI

EINSTEIN TELESCOPE

Consortium

Stan Bentvelsen
Antonio Zoccoli

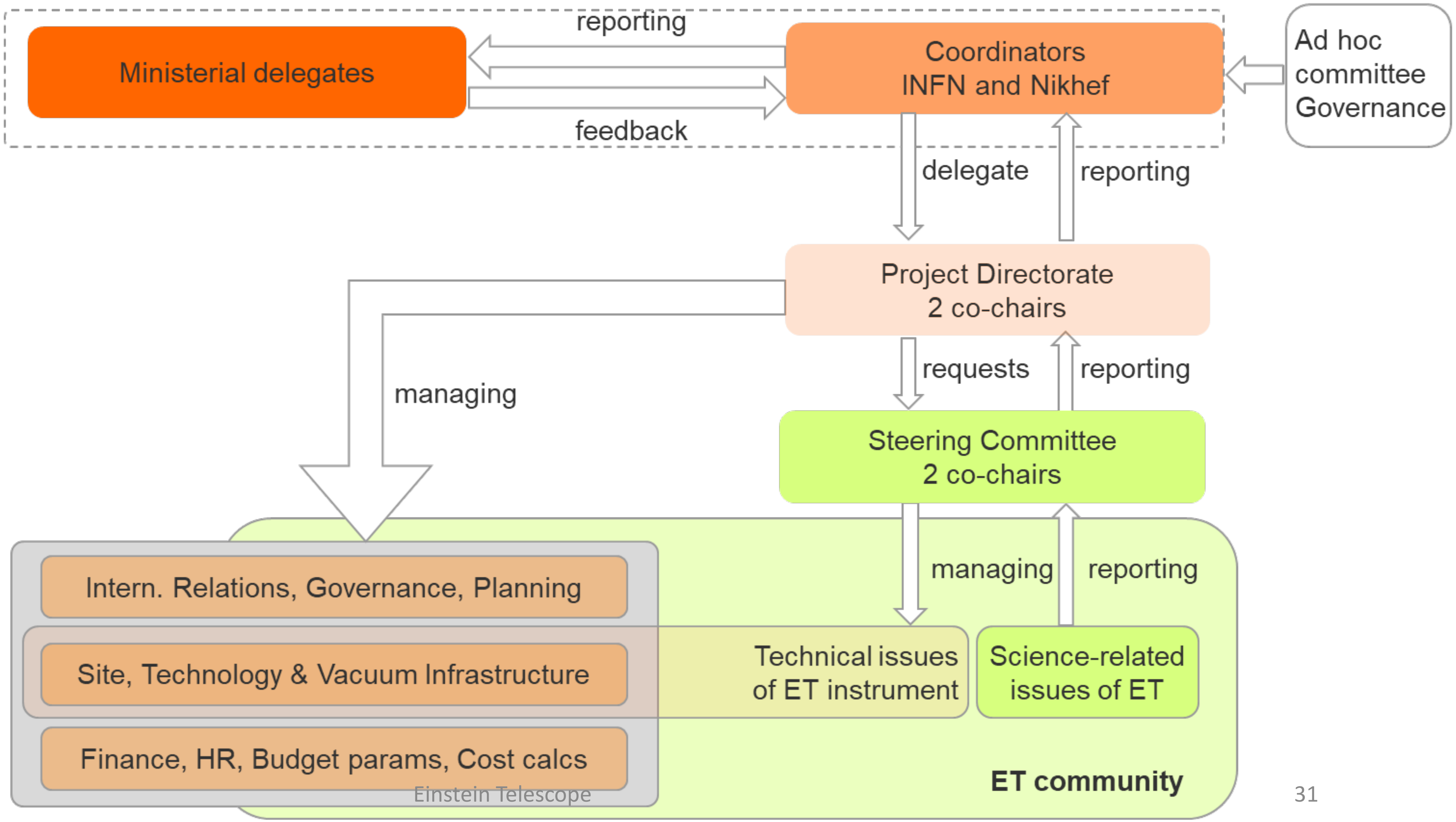
Project directorate

Jo v.d. Brand
Fernando Ferroni

ET Collaboration

Michele Punturo
Harald Lück

An *interim* structure for the ET project organization until establishment of a Council



Proposal for governance in the construction phase

Structure during Implementation phase

Council
Assisted by several bodies (*e.g.* STAC)

Project Directorate
evolves into Einstein Telescope Observatory

ET Observatory will be a legal entity
and will have significant staff

Verify by expert panel on governance and project organization