大型低温重力望遠鏡 KAGRA

大型低温重力波望遠鏡 KAGRA に関する研究（データ解析関連）

東京都市大学
総合研究所 宇宙科学研究センター
高橋弘毅（たかはし ひろたか）

E-mail : hirotaka@tcu.ac.jp

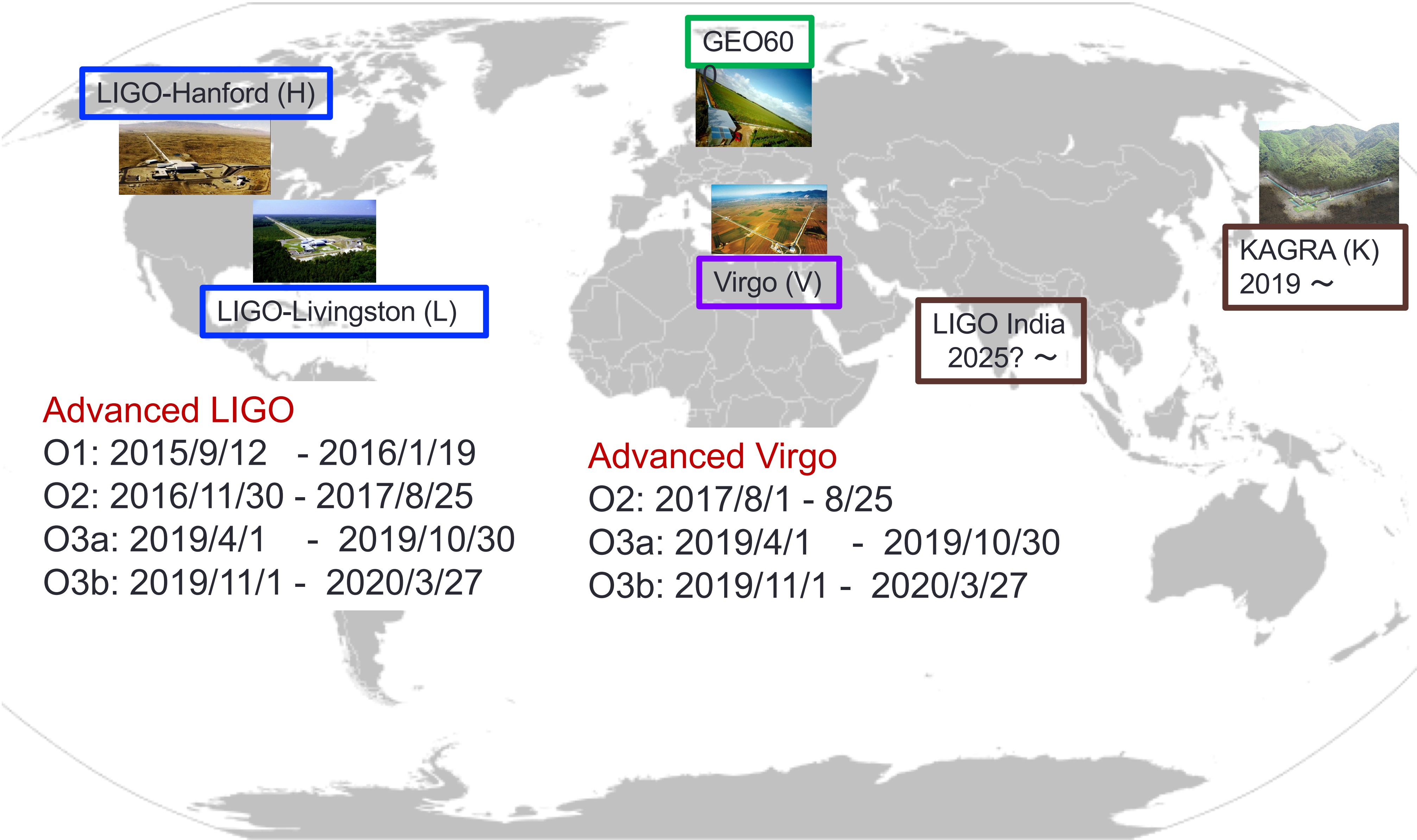
ICRR Institute for Cosmic Ray Research University of Tokyo

東京都市大学 TOKYO CITY UNIVERSITY

Contents

- LIGO/Virgo O3
- KAGRA
  - O3GK
  - Data transfer system
- Topic from ICRR Inter-University Research Program

A global GW network



Advanced LIGO

O1: 2015/9/12 - 2016/1/19
O2: 2016/11/30 - 2017/8/25
O3a: 2019/4/1 - 2019/10/30
O3b: 2019/11/1 - 2020/3/27

Advanced Virgo

O2: 2017/8/1 - 8/25
O3a: 2019/4/1 - 2019/10/30
O3b: 2019/11/1 - 2020/3/27

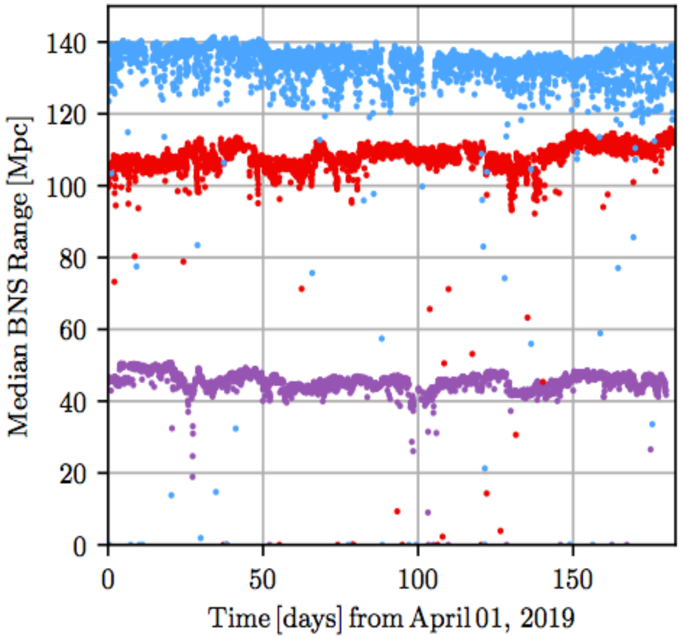
Latest LIGO-VIRGO Results

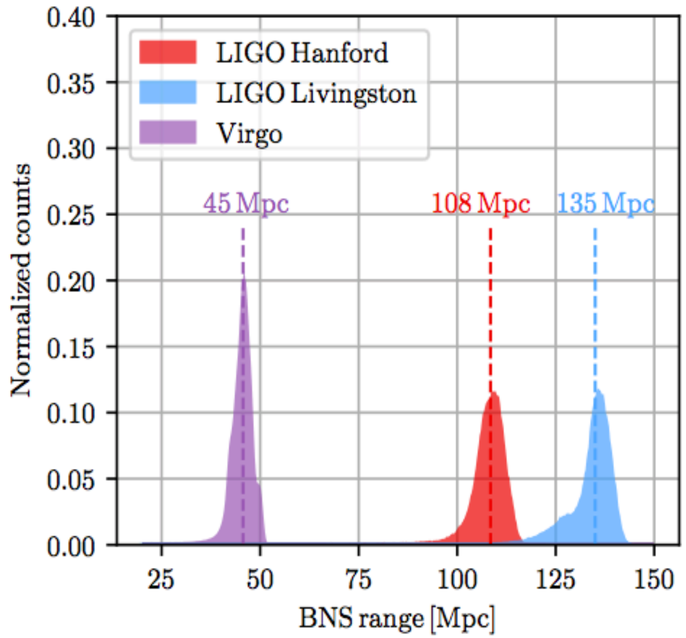
GWTC-2: Compact Binary Coalescences Observed by LIGO and Virgo During the First Half of the Third Observing Run

https://arxiv.org/abs/2010.14527

- Latest observation
  - O3a April 1 – Oct 1st, 2019

    (O3b Nov 1, 2019 – Mar 27, 2020)





- Network duty factor:
  triple 44.5%, double 37.4%, single 15.0% Down 3.1%

LIGO-Virgo O3a catalog

2019/4/1, 15:00 UTC – 2019/10/1, 15:00 UTC

39 candidates

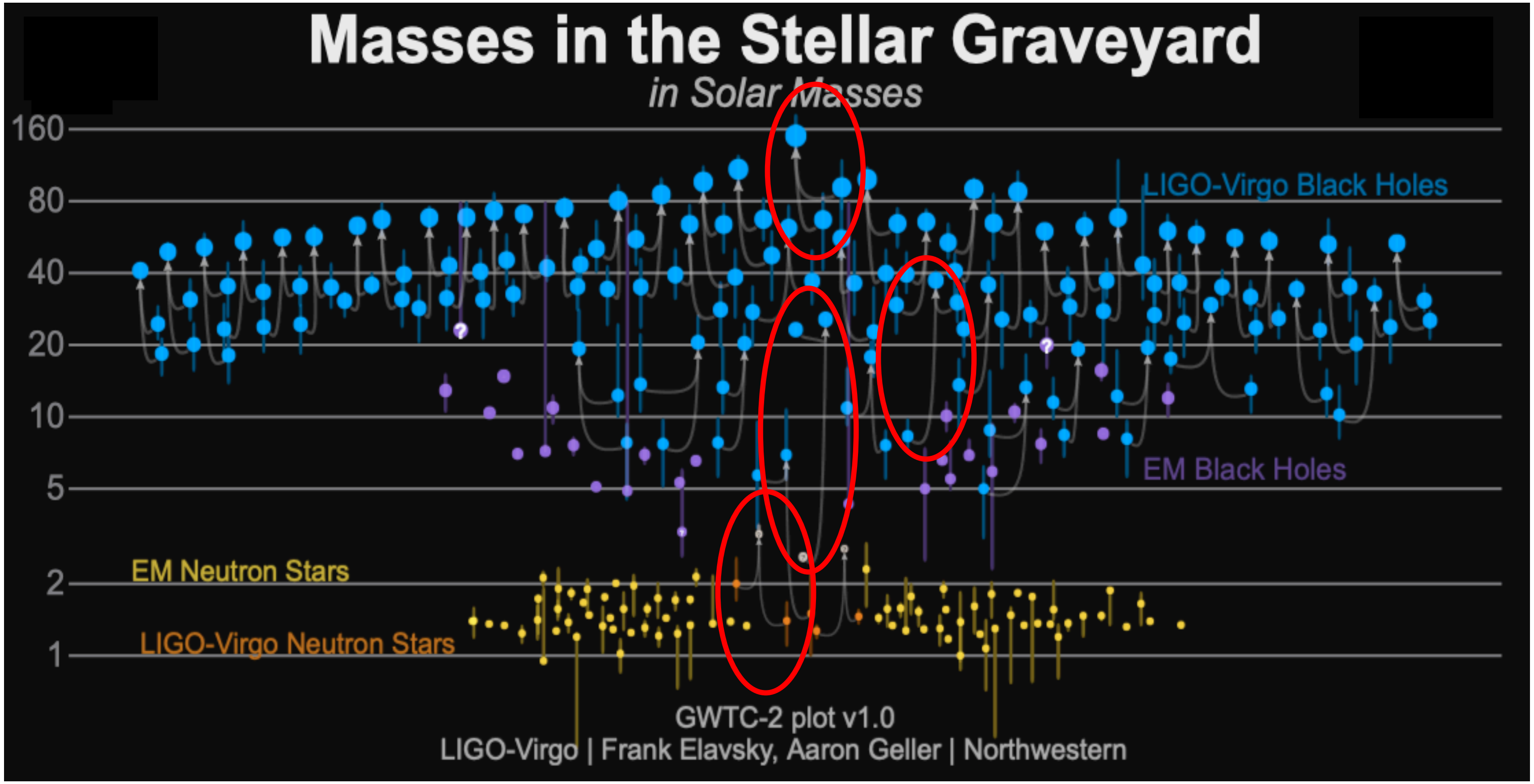
GWTC-2: Compact Binary Coalescences Observed by LIGO and Virgo During the First Half of the Third Observing Run

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	$42.9^{+4.1}_{-2.9}$	$18.3^{+1.8}_{-1.2}$	$24.5^{+5.1}_{-3.4}$	$18.3^{+3.2}_{-3.5}$	$-0.03^{+0.13}_{-0.19}$	$1.58^{+0.40}_{-0.59}$	$0.30^{+0.06}_{-0.10}$	$41.0^{+3.8}_{-2.7}$	$0.67^{+0.06}_{-0.07}$	140	$15.3^{+0.2}_{-0.3}$
GW190412	$38.4^{+3.8}_{-3.7}$	$13.3^{+0.4}_{-0.3}$	$30.0^{+4.7}_{-5.1}$	$8.3^{+1.6}_{-0.9}$	$0.25^{+0.08}_{-0.11}$	$0.74^{+0.14}_{-0.17}$	$0.15^{+0.03}_{-0.03}$	$37.3^{+3.9}_{-3.9}$	$0.67^{+0.05}_{-0.06}$	21	$18.9^{+0.2}_{-0.3}$
GW190413_052954	$56.9^{+13.1}_{-8.9}$	$24.0^{+5.4}_{-3.7}$	$33.4^{+12.4}_{-7.4}$	$23.4^{+6.7}_{-6.3}$	$0.01^{+0.29}_{-0.33}$	$4.10^{+2.41}_{-1.89}$	$0.66^{+0.30}_{-0.27}$	$54.3^{+12.4}_{-8.4}$	$0.69^{+0.12}_{-0.13}$	1400	$8.9^{+0.4}_{-0.8}$
GW190413_134308	$76.1^{+15.9}_{-10.6}$	$31.9^{+7.3}_{-4.6}$	$45.4^{+13.6}_{-9.6}$	$30.9^{+10.2}_{-9.6}$	$-0.01^{+0.24}_{-0.28}$	$5.15^{+2.44}_{-2.34}$	$0.80^{+0.30}_{-0.31}$	$72.8^{+15.2}_{-10.3}$	$0.69^{+0.10}_{-0.12}$	520	$10.0^{+0.4}_{-0.5}$
GW190421_213856	$71.8^{+12.5}_{-8.6}$	$30.7^{+5.5}_{-3.9}$	$40.6^{+10.4}_{-6.6}$	$31.4^{+7.5}_{-8.2}$	$-0.05^{+0.23}_{-0.26}$	$3.15^{+1.37}_{-1.42}$	$0.53^{+0.18}_{-0.21}$	$68.6^{+11.7}_{-8.1}$	$0.68^{+0.10}_{-0.11}$	1000	$10.7^{+0.2}_{-0.4}$
GW190424_180648	$70.7^{+13.4}_{-9.8}$	$30.3^{+5.7}_{-4.2}$	$39.5^{+10.9}_{-6.9}$	$31.0^{+7.4}_{-7.3}$	$0.15^{+0.22}_{-0.22}$	$2.55^{+1.56}_{-1.33}$	$0.45^{+0.22}_{-0.21}$	$67.1^{+12.5}_{-9.2}$	$0.75^{+0.08}_{-0.09}$	26000	$10.4^{+0.2}_{-0.4}$
GW190425	$3.4^{+0.3}_{-0.1}$	$1.44^{+0.02}_{-0.02}$	$2.0^{+0.6}_{-0.3}$	$1.4^{+0.3}_{-0.3}$	$0.06^{+0.11}_{-0.05}$	$0.16^{+0.07}_{-0.07}$	$0.03^{+0.01}_{-0.02}$	–	–	9900	$12.4^{+0.3}_{-0.4}$
GW190426_152155	$7.2^{+3.5}_{-1.5}$	$2.41^{+0.08}_{-0.08}$	$5.7^{+4.0}_{-2.3}$	$1.5^{+0.8}_{-0.5}$	$-0.03^{+0.33}_{-0.30}$	$0.38^{+0.19}_{-0.16}$	$0.08^{+0.04}_{-0.03}$	–	–	1400	$8.7^{+0.5}_{-0.6}$
GW190503_185404	$71.3^{+9.3}_{-8.0}$	$30.1^{+4.2}_{-4.0}$	$42.9^{+9.2}_{-7.8}$	$28.5^{+7.5}_{-7.9}$	$-0.02^{+0.20}_{-0.26}$	$1.52^{+0.71}_{-0.66}$	$0.29^{+0.11}_{-0.11}$	$68.2^{+8.7}_{-7.5}$	$0.67^{+0.09}_{-0.12}$	94	$12.4^{+0.2}_{-0.3}$
GW190512_180714	$35.6^{+3.9}_{-3.4}$	$14.5^{+1.3}_{-1.0}$	$23.0^{+5.4}_{-5.7}$	$12.5^{+3.5}_{-2.5}$	$0.03^{+0.13}_{-0.13}$	$1.49^{+0.53}_{-0.59}$	$0.28^{+0.09}_{-0.10}$	$34.2^{+3.9}_{-3.4}$	$0.65^{+0.07}_{-0.07}$	230	$12.2^{+0.2}_{-0.4}$
GW190513_205428	$53.6^{+8.6}_{-5.9}$	$21.5^{+3.6}_{-1.9}$	$35.3^{+9.6}_{-9.0}$	$18.1^{+7.3}_{-4.2}$	$0.12^{+0.29}_{-0.18}$	$2.16^{+0.94}_{-0.80}$	$0.39^{+0.14}_{-0.13}$	$51.3^{+8.1}_{-5.8}$	$0.69^{+0.14}_{-0.12}$	490	$12.9^{+0.3}_{-0.4}$
GW190514_065416	$64.2^{+16.6}_{-9.6}$	$27.4^{+6.9}_{-4.3}$	$36.9^{+13.4}_{-7.3}$	$27.5^{+8.2}_{-7.7}$	$-0.16^{+0.28}_{-0.32}$	$4.93^{+2.76}_{-2.41}$	$0.77^{+0.34}_{-0.33}$	$61.6^{+16.0}_{-9.2}$	$0.64^{+0.11}_{-0.14}$	2400	$8.2^{+0.3}_{-0.6}$
GW190517_055101	$61.9^{+10.0}_{-9.6}$	$26.0^{+4.2}_{-4.0}$	$36.4^{+11.8}_{-7.8}$	$24.8^{+6.9}_{-7.1}$	$0.53^{+0.20}_{-0.19}$	$2.11^{+1.79}_{-1.00}$	$0.38^{+0.26}_{-0.16}$	$57.8^{+9.4}_{-9.1}$	$0.87^{+0.05}_{-0.07}$	460	$10.7^{+0.4}_{-0.6}$
GW190519_153544	$104.2^{+14.5}_{-14.9}$	$43.5^{+6.8}_{-6.8}$	$64.5^{+11.3}_{-13.2}$	$39.9^{+11.0}_{-10.6}$	$0.33^{+0.19}_{-0.22}$	$2.85^{+2.02}_{-1.14}$	$0.49^{+0.27}_{-0.17}$	$98.7^{+13.5}_{-14.2}$	$0.80^{+0.07}_{-0.12}$	770	$15.6^{+0.2}_{-0.3}$
GW190521	$157.9^{+37.4}_{-20.9}$	$66.9^{+15.5}_{-9.2}$	$91.4^{+29.3}_{-17.5}$	$66.8^{+20.7}_{-20.7}$	$0.06^{+0.31}_{-0.37}$	$4.53^{+2.30}_{-2.13}$	$0.72^{+0.29}_{-0.29}$	$150.3^{+35.8}_{-20.0}$	$0.73^{+0.11}_{-0.14}$	940	$14.2^{+0.3}_{-0.3}$
GW190521_074359	$74.4^{+6.8}_{-4.6}$	$31.9^{+3.1}_{-2.4}$	$42.1^{+5.9}_{-4.9}$	$32.7^{+5.4}_{-6.2}$	$0.09^{+0.10}_{-0.13}$	$1.28^{+0.38}_{-0.57}$	$0.25^{+0.06}_{-0.10}$	$70.7^{+6.4}_{-4.2}$	$0.72^{+0.05}_{-0.07}$	500	$25.8^{+0.1}_{-0.2}$
GW190527_092055	$58.5^{+27.9}_{-10.6}$	$24.2^{+11.9}_{-4.4}$	$36.2^{+19.1}_{-9.5}$	$22.8^{+12.7}_{-8.1}$	$0.13^{+0.29}_{-0.28}$	$3.10^{+4.85}_{-1.64}$	$0.53^{+0.61}_{-0.25}$	$55.9^{+26.4}_{-10.1}$	$0.73^{+0.12}_{-0.16}$	3800	$8.1^{+0.4}_{-1.0}$
GW190602_175927	$114.1^{+18.5}_{-15.7}$	$48.3^{+8.6}_{-8.0}$	$67.2^{+16.0}_{-12.6}$	$47.4^{+13.4}_{-16.6}$	$0.10^{+0.25}_{-0.25}$	$2.99^{+2.02}_{-1.26}$	$0.51^{+0.27}_{-0.19}$	$108.8^{+17.2}_{-14.8}$	$0.71^{+0.10}_{-0.13}$	720	$12.8^{+0.2}_{-0.3}$
GW190620_030421	$90.1^{+17.3}_{-12.1}$	$37.5^{+7.8}_{-5.7}$	$55.4^{+15.8}_{-12.0}$	$35.0^{+11.6}_{-11.4}$	$0.34^{+0.21}_{-0.25}$	$3.16^{+1.67}_{-1.43}$	$0.54^{+0.22}_{-0.21}$	$85.4^{+15.9}_{-11.4}$	$0.80^{+0.08}_{-0.14}$	6700	$12.1^{+0.3}_{-0.4}$
GW190630_185205	$58.8^{+4.7}_{-4.8}$	$24.8^{+2.1}_{-2.0}$	$35.0^{+6.9}_{-5.7}$	$23.6^{+5.2}_{-5.1}$	$0.10^{+0.12}_{-0.13}$	$0.93^{+0.56}_{-0.40}$	$0.19^{+0.10}_{-0.07}$	$56.1^{+4.5}_{-4.6}$	$0.70^{+0.06}_{-0.07}$	1300	$15.6^{+0.2}_{-0.3}$
GW190701_203306	$94.1^{+11.6}_{-9.3}$	$40.2^{+5.2}_{-4.7}$	$53.6^{+11.7}_{-7.8}$	$40.8^{+8.3}_{-11.5}$	$-0.06^{+0.23}_{-0.28}$	$2.14^{+0.79}_{-0.73}$	$0.38^{+0.12}_{-0.12}$	$90.0^{+10.8}_{-8.6}$	$0.67^{+0.09}_{-0.12}$	45	$11.3^{+0.2}_{-0.4}$
GW190706_222641	$101.6^{+17.9}_{-13.5}$	$42.0^{+8.4}_{-6.2}$	$64.0^{+15.2}_{-15.2}$	$38.5^{+12.5}_{-12.4}$	$0.32^{+0.25}_{-0.30}$	$5.07^{+2.57}_{-2.11}$	$0.79^{+0.31}_{-0.28}$	$96.3^{+16.7}_{-13.2}$	$0.80^{+0.08}_{-0.17}$	610	$12.6^{+0.2}_{-0.4}$
GW190707_093326	$20.0^{+1.9}_{-1.3}$	$8.5^{+0.6}_{-0.4}$	$11.5^{+3.3}_{-1.7}$	$8.4^{+1.4}_{-1.6}$	$-0.05^{+0.10}_{-0.08}$	$0.80^{+0.37}_{-0.38}$	$0.16^{+0.07}_{-0.07}$	$19.2^{+1.9}_{-1.3}$	$0.66^{+0.03}_{-0.04}$	1300	$13.3^{+0.2}_{-0.4}$
GW190708_232457	$30.8^{+2.5}_{-1.8}$	$13.1^{+0.9}_{-0.6}$	$17.5^{+4.7}_{-2.3}$	$13.1^{+2.0}_{-2.7}$	$0.02^{+0.10}_{-0.08}$	$0.90^{+0.33}_{-0.40}$	$0.18^{+0.06}_{-0.07}$	$29.4^{+2.5}_{-1.7}$	$0.69^{+0.04}_{-0.04}$	14000	$13.1^{+0.2}_{-0.3}$
GW190719_215514	$55.8^{+16.3}_{-10.0}$	$22.7^{+5.9}_{-3.7}$	$35.2^{+16.9}_{-9.9}$	$20.2^{+8.1}_{-6.5}$	$0.35^{+0.28}_{-0.32}$	$4.61^{+2.84}_{-2.17}$	$0.73^{+0.35}_{-0.30}$	$52.9^{+15.6}_{-9.5}$	$0.80^{+0.10}_{-0.16}$	2300	$8.3^{+0.3}_{-1.0}$
GW190720_000836	$21.3^{+4.3}_{-2.3}$	$8.9^{+0.5}_{-0.8}$	$13.3^{+6.6}_{-3.0}$	$7.8^{+2.2}_{-2.2}$	$0.18^{+0.14}_{-0.12}$	$0.81^{+0.71}_{-0.33}$	$0.16^{+0.12}_{-0.06}$	$20.3^{+4.5}_{-2.3}$	$0.72^{+0.06}_{-0.05}$	510	$11.0^{+0.3}_{-0.8}$
GW190727_060333	$65.8^{+10.9}_{-7.4}$	$28.1^{+4.9}_{-3.4}$	$37.2^{+9.4}_{-5.9}$	$28.8^{+6.6}_{-7.9}$	$0.12^{+0.26}_{-0.25}$	$3.60^{+1.56}_{-1.51}$	$0.60^{+0.20}_{-0.22}$	$62.6^{+10.2}_{-7.0}$	$0.73^{+0.10}_{-0.10}$	860	$11.9^{+0.3}_{-0.5}$
GW190728_064510	$20.5^{+4.5}_{-1.3}$	$8.6^{+0.5}_{-0.3}$	$12.2^{+7.1}_{-2.2}$	$8.1^{+1.7}_{-2.6}$	$0.12^{+0.19}_{-0.07}$	$0.89^{+0.25}_{-0.37}$	$0.18^{+0.05}_{-0.07}$	$19.5^{+4.6}_{-1.3}$	$0.71^{+0.04}_{-0.04}$	410	$13.0^{+0.2}_{-0.4}$
GW190731_140936	$67.1^{+15.3}_{-10.2}$	$28.4^{+6.8}_{-4.5}$	$39.3^{+11.8}_{-8.2}$	$28.0^{+8.9}_{-8.4}$	$0.08^{+0.24}_{-0.24}$	$3.97^{+2.56}_{-2.07}$	$0.65^{+0.32}_{-0.30}$	$63.9^{+14.4}_{-9.8}$	$0.71^{+0.10}_{-0.12}$	3000	$8.6^{+0.2}_{-0.5}$
GW190803_022701	$62.7^{+11.8}_{-8.4}$	$26.7^{+5.2}_{-3.8}$	$36.1^{+10.2}_{-6.7}$	$26.7^{+7.1}_{-7.6}$	$-0.01^{+0.25}_{-0.26}$	$3.69^{+2.04}_{-1.69}$	$0.61^{+0.26}_{-0.24}$	$59.9^{+11.2}_{-7.9}$	$0.69^{+0.10}_{-0.11}$	1500	$8.6^{+0.3}_{-0.5}$
GW190814	$25.8^{+1.0}_{-0.9}$	$6.09^{+0.06}_{-0.06}$	$23.2^{+1.1}_{-1.0}$	$2.59^{+0.08}_{-0.09}$	$0.00^{+0.06}_{-0.06}$	$0.24^{+0.04}_{-0.05}$	$0.05^{+0.009}_{-0.010}$	$25.6^{+1.0}_{-0.9}$	$0.28^{+0.02}_{-0.02}$	19	$24.9^{+0.1}_{-0.2}$
GW190828_063405	$57.5^{+7.5}_{-4.4}$	$24.8^{+3.3}_{-2.0}$	$31.8^{+5.8}_{-3.9}$	$25.9^{+4.4}_{-4.6}$	$0.19^{+0.15}_{-0.16}$	$2.22^{+0.63}_{-0.95}$	$0.40^{+0.09}_{-0.15}$	$54.5^{+6.9}_{-4.0}$	$0.76^{+0.06}_{-0.07}$	520	$16.2^{+0.2}_{-0.3}$
GW190828_065509	$34.1^{+5.5}_{-4.5}$	$13.3^{+1.2}_{-0.9}$	$23.8^{+7.2}_{-7.0}$	$10.2^{+3.5}_{-2.1}$	$0.08^{+0.16}_{-0.16}$	$1.66^{+0.63}_{-0.61}$	$0.31^{+0.10}_{-0.10}$	$32.9^{+5.7}_{-4.5}$	$0.65^{+0.09}_{-0.08}$	640	$10.0^{+0.3}_{-0.5}$
GW190909_114149	$71.2^{+54.3}_{-15.0}$	$29.5^{+17.5}_{-6.3}$	$43.2^{+50.7}_{-12.2}$	$27.6^{+13.0}_{-10.9}$	$-0.03^{+0.44}_{-0.36}$	$4.77^{+3.70}_{-2.66}$	$0.75^{+0.45}_{-0.37}$	$68.3^{+52.5}_{-14.5}$	$0.68^{+0.16}_{-0.18}$	4200	$8.1^{+0.4}_{-0.7}$
GW190910_112807	$78.7^{+9.5}_{-9.0}$	$33.9^{+4.3}_{-3.9}$	$43.5^{+7.6}_{-6.2}$	$35.1^{+6.3}_{-7.0}$	$0.02^{+0.19}_{-0.18}$	$1.57^{+1.07}_{-0.64}$	$0.29^{+0.17}_{-0.11}$	$75.0^{+8.7}_{-8.5}$	$0.70^{+0.08}_{-0.07}$	10000	$14.1^{+0.2}_{-0.3}$
GW190915_235702	$59.5^{+7.5}_{-6.2}$	$25.1^{+3.1}_{-2.6}$	$34.9^{+9.5}_{-6.2}$	$24.4^{+5.5}_{-6.0}$	$0.03^{+0.19}_{-0.24}$	$1.70^{+0.71}_{-0.64}$	$0.32^{+0.11}_{-0.11}$	$56.8^{+7.1}_{-5.8}$	$0.71^{+0.09}_{-0.11}$	380	$13.6^{+0.2}_{-0.3}$
GW190924_021846	$13.9^{+5.1}_{-0.9}$	$5.8^{+0.2}_{-0.2}$	$8.8^{+7.0}_{-2.0}$	$5.0^{+1.3}_{-1.9}$	$0.03^{+0.30}_{-0.09}$	$0.57^{+0.22}_{-0.22}$	$0.12^{+0.04}_{-0.04}$	$13.3^{+5.2}_{-1.0}$	$0.67^{+0.05}_{-0.05}$	380	$11.5^{+0.3}_{-0.4}$
GW190929_012149	$90.6^{+21.2}_{-14.1}$	$34.3^{+8.6}_{-6.5}$	$64.7^{+22.4}_{-18.9}$	$25.7^{+14.4}_{-9.7}$	$0.03^{+0.27}_{-0.27}$	$3.68^{+2.98}_{-1.68}$	$0.61^{+0.38}_{-0.24}$	$87.5^{+20.7}_{-14.1}$	$0.64^{+0.17}_{-0.23}$	1800	$9.8^{+0.8}_{-0.6}$
GW190930_133541	$20.3^{+9.0}_{-1.5}$	$8.5^{+0.5}_{-0.5}$	$12.3^{+12.5}_{-2.3}$	$7.8^{+1.7}_{-3.3}$	$0.14^{+0.31}_{-0.15}$	$0.78^{+0.37}_{-0.33}$	$0.16^{+0.07}_{-0.06}$	$19.3^{+9.3}_{-1.5}$	$0.72^{+0.07}_{-0.06}$	1800	$9.5^{+0.3}_{-0.5}$

https://arxiv.org/abs/2010.14527

https://www.ligo.org/science/Publication-O3aCatalog/index.php

After O3a：GWTC2 (2020/10/28 released)



46 BHBH
2 NSNS
2 BH+?

https://media.ligo.northwestern.edu/gallery/mass-plot

- GW190412: the first BBH with definitively asymmetric component masses, which also shows evidence for higher harmonics
- GW190425: the second gravitational-wave event consistent with a BNS, following GW170817 (30solar mass + 8.3 solar mass)
- GW190426_152155: a low-mass event consistent with either an NSBH or BBH
- GW190514_065416: a BBH with the smallest effective aligned spin of all O3a events
- GW190517_055101: a BBH with the largest effective aligned spin of all O3a events
- GW190521: a BBH with total mass over 150 times the mass of the Sun
- GW190814: a highly asymmetric system of ambiguous nature, corresponding to the merger of a 23 solar mass black hole with a 2.6 solar mass compact object, making the latter either the lightest black hole or heaviest neutron star observed in a compact binary
- GW190924_021846: likely the lowest-mass BBH, with both black holes exceeding 3 solar masses

BBH merger rate

Before O1
Class. Quantum Grav. **27** (2010) 173001

0.1 – 300 /Gpc^3/yr

↓

O1
PHYSICAL REVIEW X 6, 041015 (2016)

9 – 240 /Gpc^3/yr

↓

O1 & O2
PHYSICAL REVIEW X 9, 031040 (2019)

9.7 – 101 /Gpc^3/yr

↓

O1 & O2 & O3a
arXiv: 2010.14533

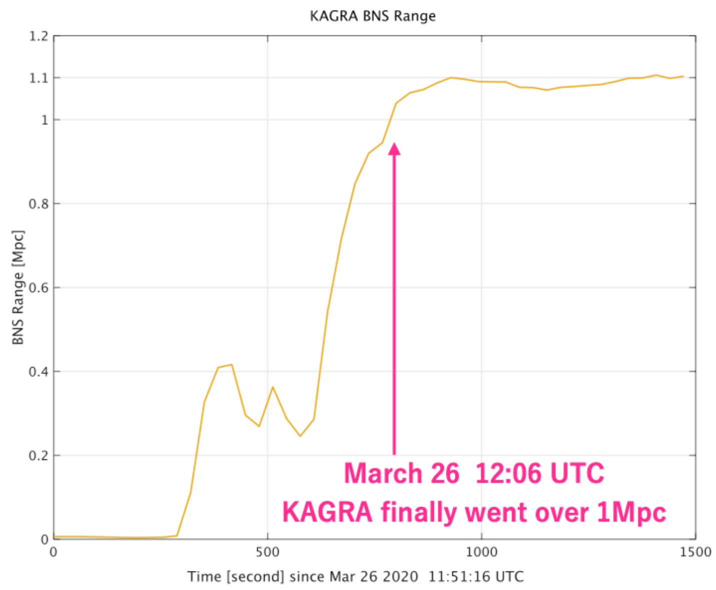
15.3 – 38.8 /Gpc^3/yr

↓

O1 & O2 & O3a & O3b & O4

?

Overview of O3GK



- Initial plan:
  - Join the O3 observation coordinated by LIGO and Virgo, once KAGRA sensitivity reached the goal sensitivity decided on MoA.
- Actual situation:
  - We reached the goal sensitivity at the end of March, 2020.
  - However, LIGO and Virgo stopped their operation due to COVID-19 infection.
  - Under such a situation, GEO600, Germany, and KAGRA carried out a joint observation run in April, 2020.
  - This was first joint observation for KAGRA
  - This observation run was named 'O3GK'

LIGO-Virgo-KAGRAの協定に基づいて行われた正式な観測運転

O3GK

[Feb. 20th - Feb. 25th, 2020] Engineering Run

[Feb. 25th - Mar. 10th, 2020] KAGRA solo observation run

[Mar. 10th - Mar. 31st, 2020] Commissioning break

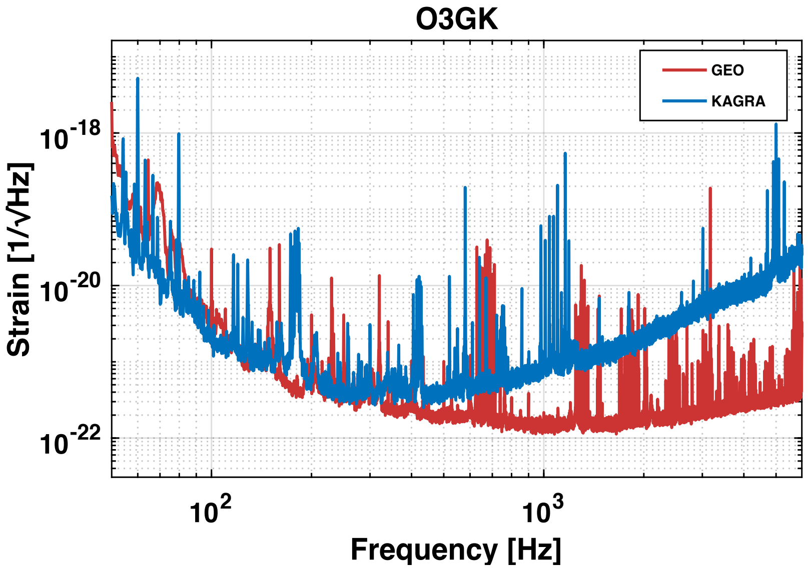
[Mar. 31st - Apr. 7th, 2020] Engineering run

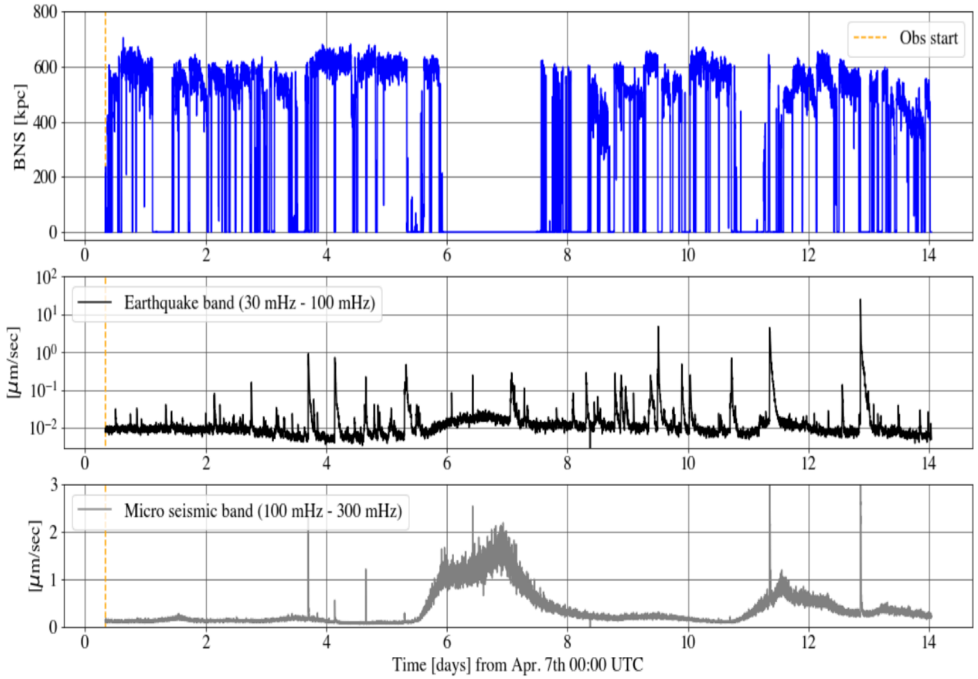
[Apr. 7th UTC 8:00 - Apr. 21st UTC 00:00, 2020] Observing run (O3GK)

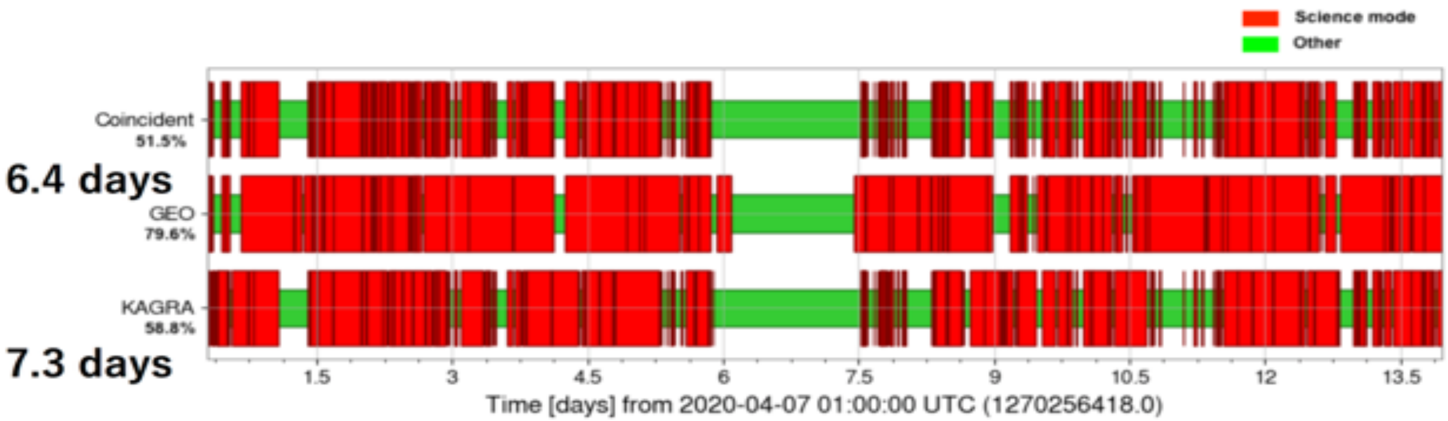
- [Apr. 7th, 2020] Weekly maintenance & calib. measurement
- [Apr. 15th, 2020] GRB200415A !!
- [Apr. 16th, 2020] Weekly maintenance & calib. Measurement

[Apr. 21st - Apr. 23rd, 2020] CAL measurement days

O3GK







KAGRA:

Duty Cycle: 53.2 % (Science run mode) / 58.8 % (Locked)
Typical binary range: ~600 kpc

O3GK analysis

GEO data (James Lough)
Data transfer (Oohara, Kanda, James Clark)
Calibration (Sawada, Yamamoto, Inoue)
Data quality (Kozakai, Washimi, Borja Sorazu)
All sky cWB (Man Leong Chan, Hayama, Marek, Sergey, Marco Drago)
All sky GstLAL (Ueno)
GRB triggered search
- pyGRB (Andrew Williamson)
- X-pipeline (Michael Norman, Patrick Sutton)

LVKの枠組みで解析は現在進行中

KAGRA data : Transfer, Storage, Sharing

KAGRA

Data transfer and storage system is working steady.

Data from KAGRA site (Kamioka) is transferred to and stored at Tier-0 main server at Kashiwa

Distribution in the collaboration:

- Tier-1: Full mirroring at Academia Sinica (Taiwan), Partial mirroring at KISTI (Korea)
- Tier-0.5 (Bulk + low latency h(t)) : Osaka City U.
- Low latency h(t) distributions to some pipeline clusters

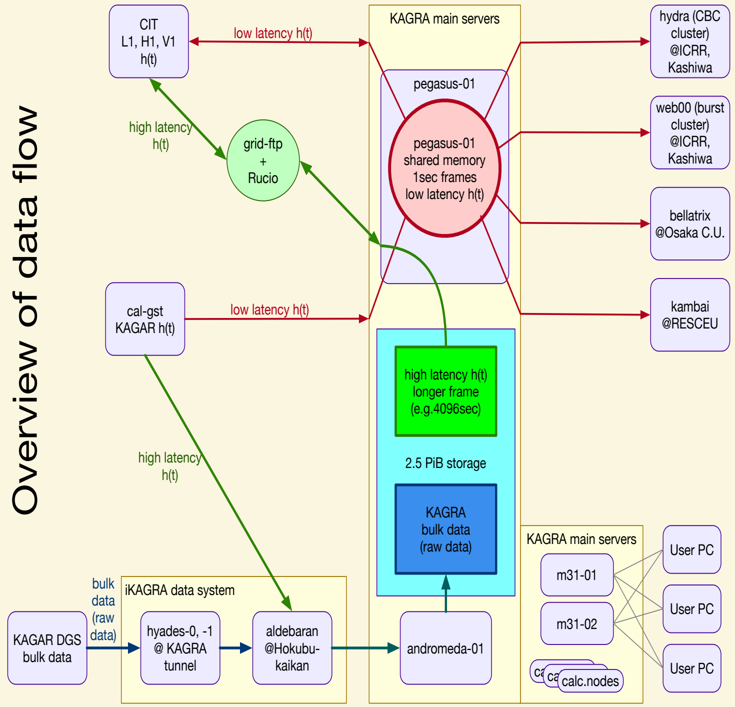
Low latency h(t) data is sharing with LIGO and Virgo

with 'framelink'

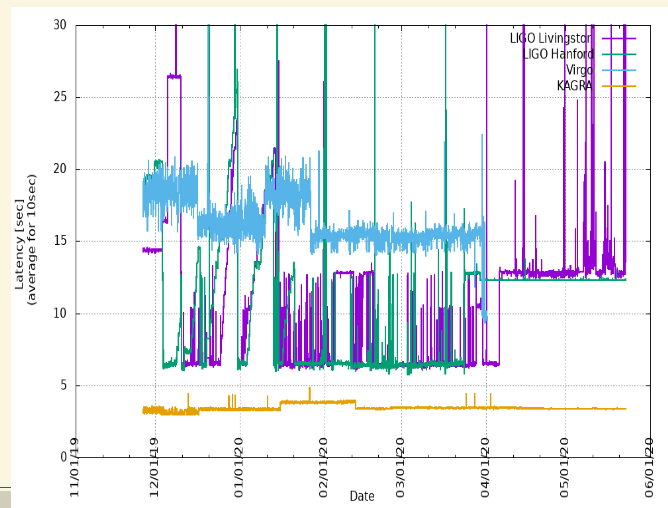
High latency h(t) data is also sharing with LV (and GEO for O3GK run)

with 'Rucio'

Overview of data flow



latency of h(t) sharing between LVK



Data and main server

KAGRA

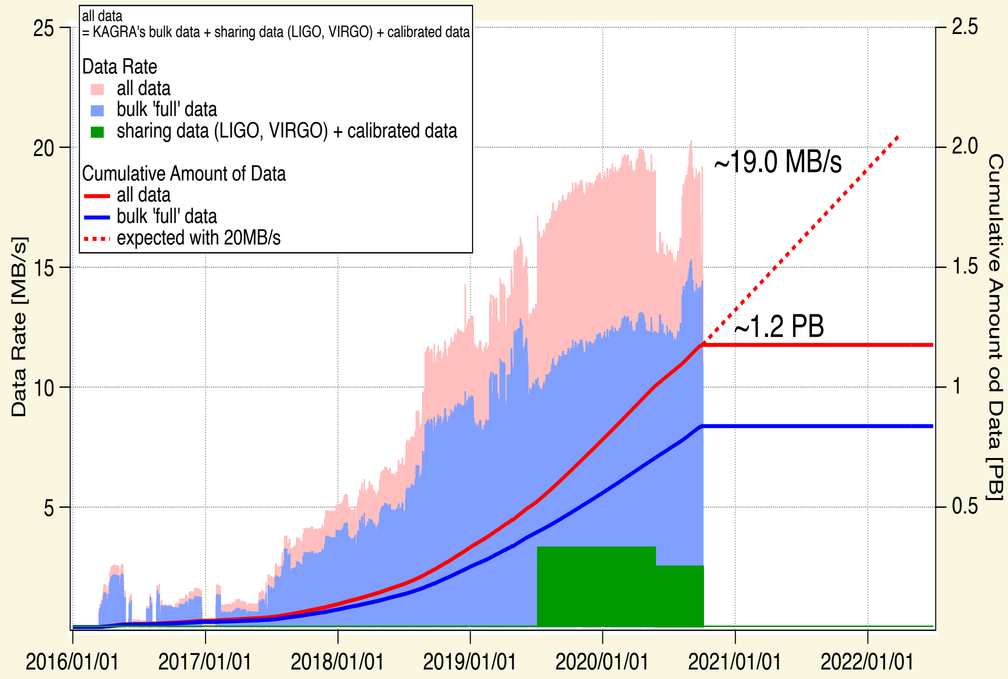
Current data rate : ~19 MB/s

Cumulative amount data : ~1.2 PiB

Next main server (system-B1)

Current main server (system-A1) at Kashiwa is expected to reach its storage capacity limit (~2.5PiB) by mid of 2022.

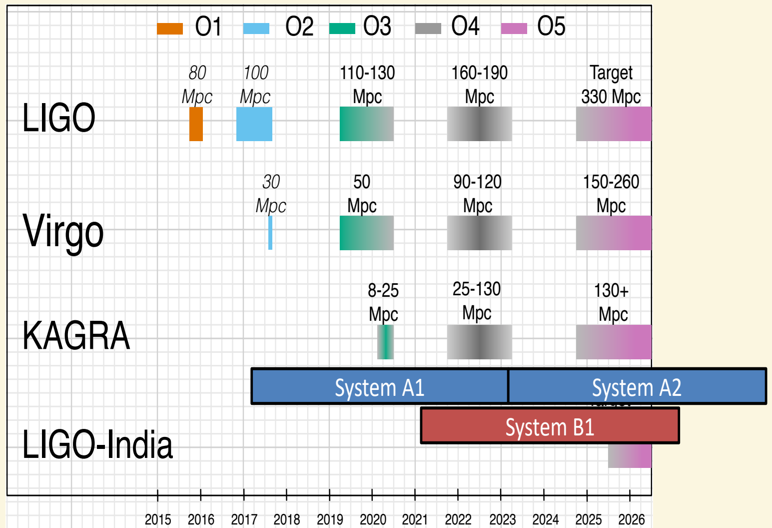
So we are starting a procurement of next server.



System-B1 requirements :

- more capacity (several PiB)
- integrated user account management with system-A1
- more CPUs as possible
- including the transfer system from Kamioka to Kashiwa

Note: Systems -A# and -B# are scheduled to be installed/updated at staggered times to enable continuous operation.



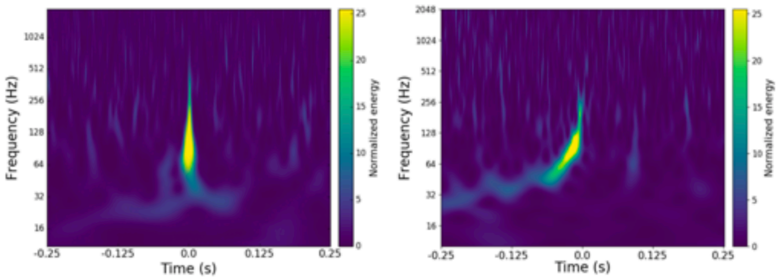
機械学習を用いた干渉計診断の研究

突発性雑音が問題になることがしばしば

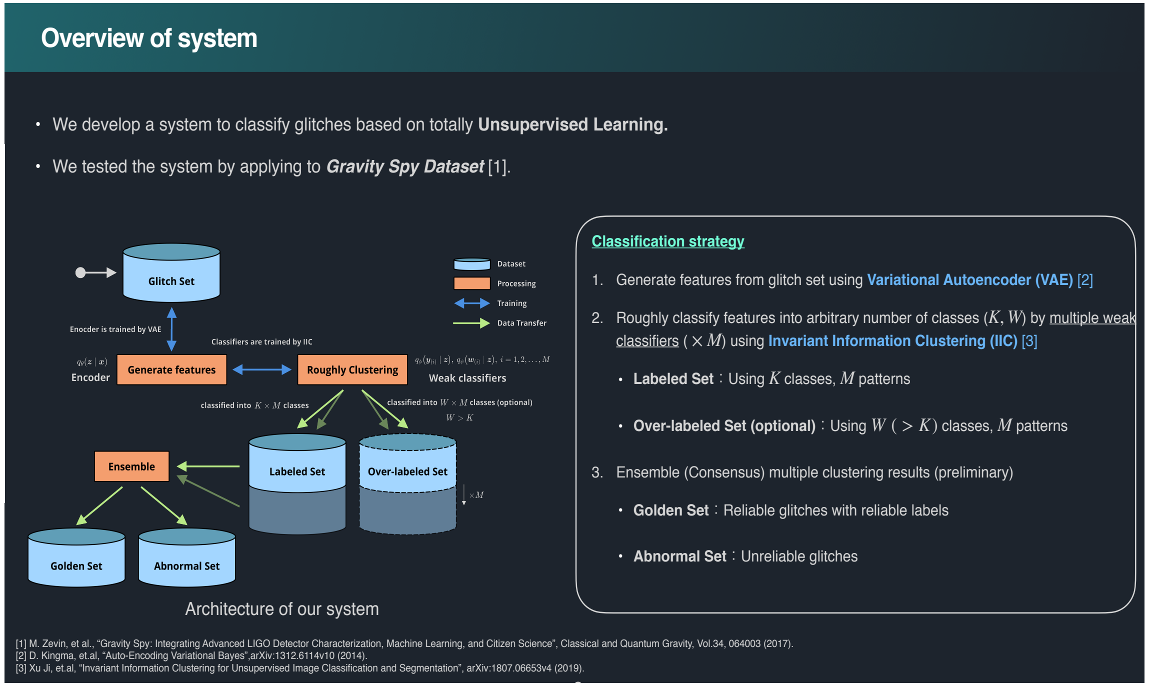
- 人手によるラベル付けを回避するために，教師なし学習に基づいて突発性雑音を分類するための新しい手段を提供
- 畳み込みニューラルネットワークモデルおよびその学習方法を提案
  - 深層学習を用いて分類に適した特徴量の生成方法を学習（Variational Autoencoder, VAE）
  - 生成された特徴量を用いて教師なし分類を行う（Invariant Information Clustering, IIC）

畳み込みニューラルネットワーク, CNN

Gravity Spy（LIGO O1 の突発性雑音データ）を用いたテスト進行中

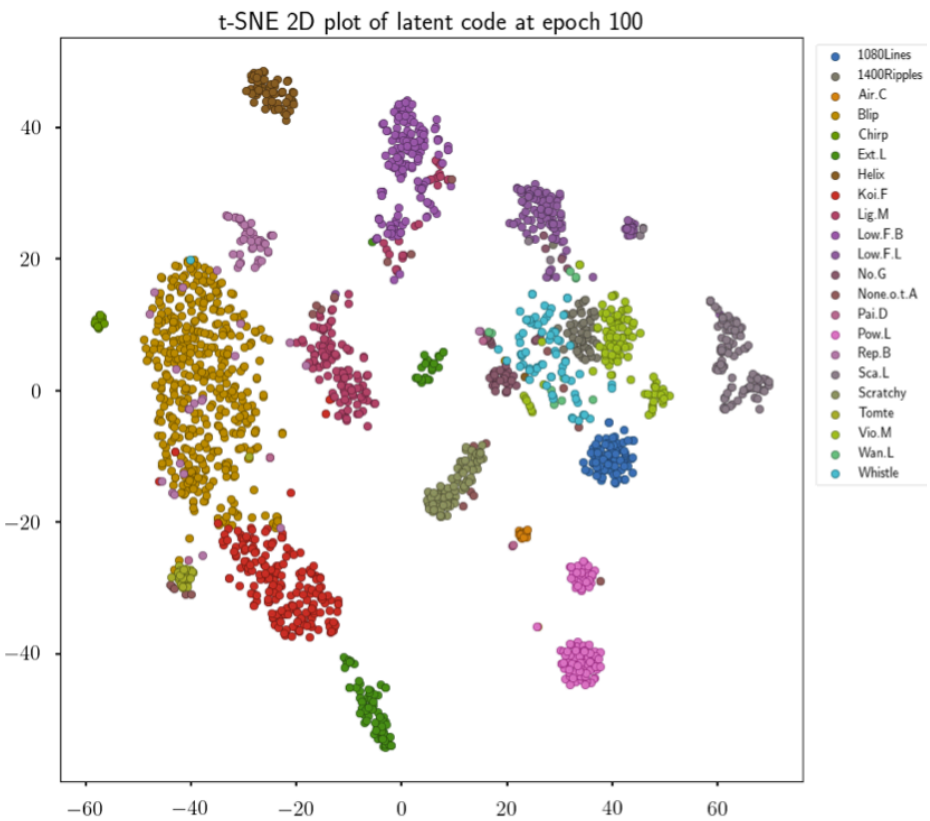


突発性雑音(左)と重力波信号(右)の時間-周波数特性

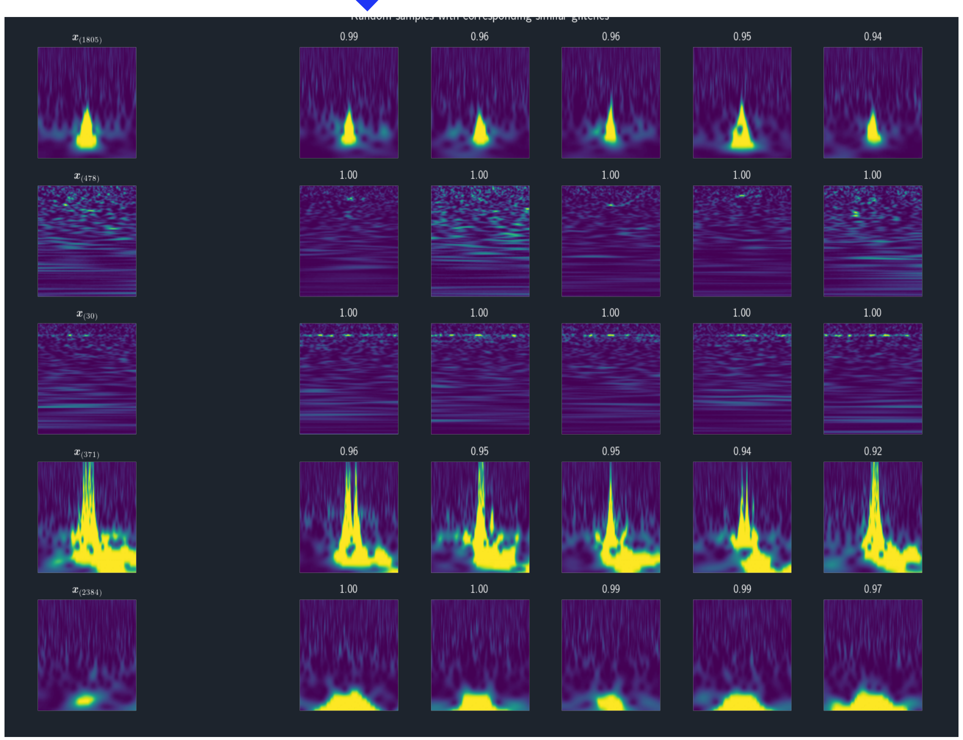


突発的雑音の分類結果の例

Preliminary



t-SNEを用いた特徴量の二次元可視化



分類されたクラス内での雑音の時間-周波数特徴

Summary

- Many analysis of O3 data are ongoing within LVK

- LVK O4 will be done with improved detector sensitivity
- More BBH/BNS detections are expected in O4 and beyond
- Detections of new sources might happen

- KAGRA is planning to participate O4 from the beginning
- We want to observe signals with KAGRA as soon as possible
- If detections with 4 detectors are realized, there are great scientific merits.