Theories of Astrophysical Big Bangs 2025 (RIKEN, Feb 17-19, 2025) KAGRA high-frequency upgrade Yuta Michimura for neutron star physics RESCEU, University of Tokyo michimura@resceu.s.u-tokyo.ac.jp For KAGRA 10yr Task Force, KAGRA Future Strategy Committee To make multi-messenger observations like GW170817 Cosmic Explorer routine, LIGO and Virgo are planning broadband upgrades,  $10^{2}$ and next-generation projects such as Einstein Telescope and Cosmic Explorer are underway. The world's only **KAGRA** upgrade? cryogenic interferometer, KAGRA, requires a different /May 2018 10 -2 10 -3 upgrade strategy, as high-frequency sensitivity demands **'KAGRA** higher laser power, while low-frequency sensitivity **Aug 2019** requires thin fibers with limited heat extraction capability.  $\geq 10^{-4}$ Binary neutron star range After evaluating various upgrade scenarios, we find that ₩ 10-5 evolution of LVK high-frequency option is the most feasible as a first  $10^{-6}$ **Nov 2019 step** towards a broadband upgrade. This upgrade would **Dec 2019** improve sky localization of binary neutron stars and enable post-merger signal detections. Mar 2020 (03GK)  $10^{-19}$ Seismic noise + Design and status of KAGRA gravity gradient May 2023 (O4a) noise is low due ₹ 10<sup>-20</sup> Virgo (3 km) **LIGO Hanford** KAGRA to underground (3 km, cryogenic) Suspension thermal noise Target by June 2025 is high due to thick sapphire KAGRA design fibers to extract heat aLIGO 2024 (O4) 10-22 aLIGO design **Quantum shot noise** A+ design (05; 2027?) is high due to limited 10-23 A# design (06; 2030?) laser power LIGO Voyager (cryo) **Mirror thermal noise LIGO Livingston NEMO** (Australia 4 km) is low due to cryogenic 10<sup>-24</sup> (4 km) **Einstein Telescope** sapphire mirror (22 K) \_IGO-India (EU 3G 10 km LF+HF (4km; 2030?~) 10<sup>-25</sup> xylophone; 2035~?)  $10^{2}$  $10^{1}$  $10^{3}$ Possible upgrade plans Cosmic Explorer frequency (Hz) (US 3G 40 km; 2035~?) Low frequency focus **Broadband plans** High frequency focus 10<sup>-21</sup>+ 10<sup>-21</sup> 3  $10^{-21}$ Post-merger signal BNS1.5-1.5 example LF2019 R. Harada+, PRD 110, at 100 Mpc Ζ - 10<sup>-22</sup> ± 10<sup>-22</sup>± 10<sup>-22</sup> ‡ LF2024 strain 10<sup>-23</sup> strain 10<sup>-23</sup> straji 10<sup>-23</sup> BBH100-100  $10^{-24}$  $10^{-24}$ at 1Gpc  $10^{-24}$ **BB2024** 10<sup>3</sup>  $10^{3}$  $10^{2}$  $10^{3}$  $10^{2}$  $10^{1}$  $10^{1}$  $10^{2}$  $10^{1}$ HF3k Baseline design frequency (Hz) frequency (Hz) frequency (Hz) HF2019 **KAGRA** LF2019 LF2024 **BB2024** HF2024 **BB2019** upgrade)  $100 \mathrm{M}_{\odot}$ 353 Mpc 277 Mpc 4927 Mpc 200 Mpc 2019 Mpc 3787 Mpc 306 Mpc 2154 Mpc 112 Mpc  $-100 \mathrm{M}_{\odot}$  $30M_{\odot}$ 6144 Mpc 4229 Mpc 552 Mpc 1088 Mpc 407 Mpc 1095 Mpc 2382 Mpc 842 Mpc 270 Mpc  $30M_{\odot}$  $1.4 M_{\odot}$ 153 Mpc 537 Mpc 133 Mpc 85 Mpc 670 Mpc 196 Mpc 178 Mpc 155 Mpc 104 Mpc  $-1.4M_{\odot}$ 2.65 deg<sup>2</sup>  $10.28 \text{ deg}^2$ **BNS** sky 10.64 deg<sup>2</sup> (HL-only)  $0.77 \text{ deg}^2$  $0.42 \text{ deg}^2$  $0.93 \, \text{deg}^2$  $0.57 \text{ deg}^2$  $0.61 \text{ deg}^2$  $\rightarrow$  1.40 deg<sup>2</sup> (with K) localization **※** BNS post-merger signal detection rate (LF & BB plans are less than 10<sup>-3</sup> events/year)  $10^{-3}$ -0.2 10<sup>-5</sup>-10<sup>-3</sup>  $10^{-3}$ -0.06 Based on merger rate estimate from O3; SNR>5. See H. Tagoshi & S. Morisaki, JGW-P2416311 for details. /year /year /year \* 40 kg  $\rightarrow$ \* Low loss \* Heavier & longer suspensions \* 30 m FC with 30 ppm loss \* Shorter and \* No FC, 10 dB SQZ Technical suspension 100 kg test mass + for 2024 ver... + for 2024 ver... thicker \* 0.75 MW arm power challenges \* Reducing vertical resonant \* 300 m FC, 10 \* Reducing vertical resonant \* Sapphire sapphire fibers \* 96% SRM | \* 99.5% birefringence | dB SQZ frequency of blade springs frequency of blade springs \* No FC, 6 dB FC = filter cavity \* 0.35 MW \* 23 kg  $\rightarrow$  40 kg test mass \* 23 kg  $\rightarrow$  **100 kg test mass** \* 1.5 MW arm **SRM** SQZ SQZ = squeezing\* No changes in the \* 30 m  $\rightarrow$  85 m FC, 9 dB SQZ \* 1.7 MW arm \* 300 m FC w/ 30 ppm loss arm power power SRM = signalsuspensions required. Can \* 1/4 coating \* 1/2 absorption \* 1.5 MW arm power power recycling mirror go to other configurations \* 1/4 coating thermal \* 90.7% SRM \* Various technical noises at thermal just by changing the SRM. \* 1/4 absorption low frequencies Which KAGRA upgrade plan do you like? References: For plans 2019 (~5-year plans), see YM+, PRD **102**, 022008 (2020) For other plans ( $\sim$ 10-year plans), see JGW-T2416182 (public document) For various science cases, see KAGRA, PTEP **2021**, 05A103 (2021)

※ Fisher analysis using IMRPhenomD waveform for GW170817-like binary at z=0.03 (127 Mpc) with two A#s and KAGRA. Median of 108 uniformly distributed sets of the source location and the polarization angle is shown.