Probing dipole radiation with the ground-based gravitational-wave observatories

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Background

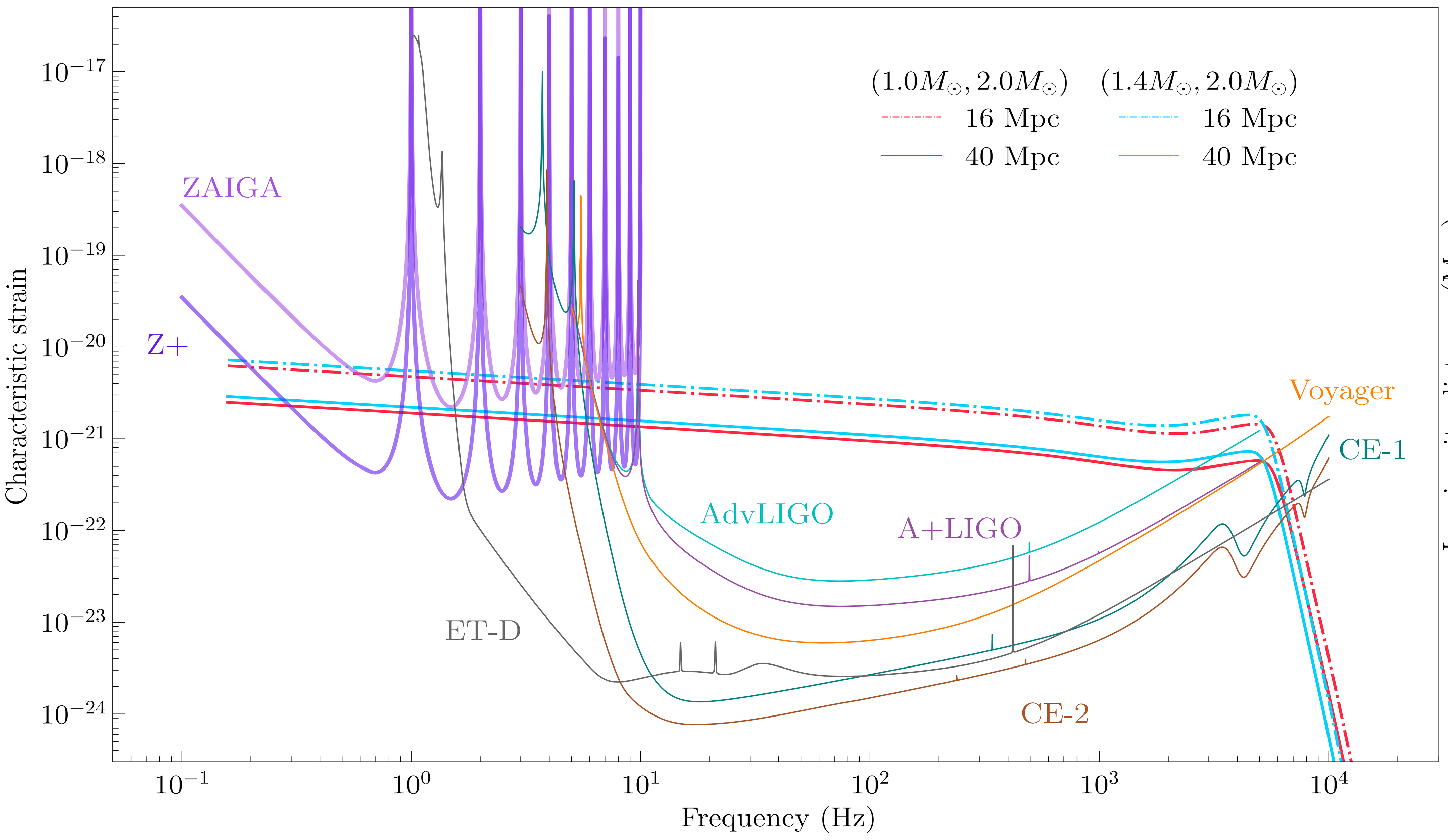
Ground-based gravitational-wave (GW) observatories we use:

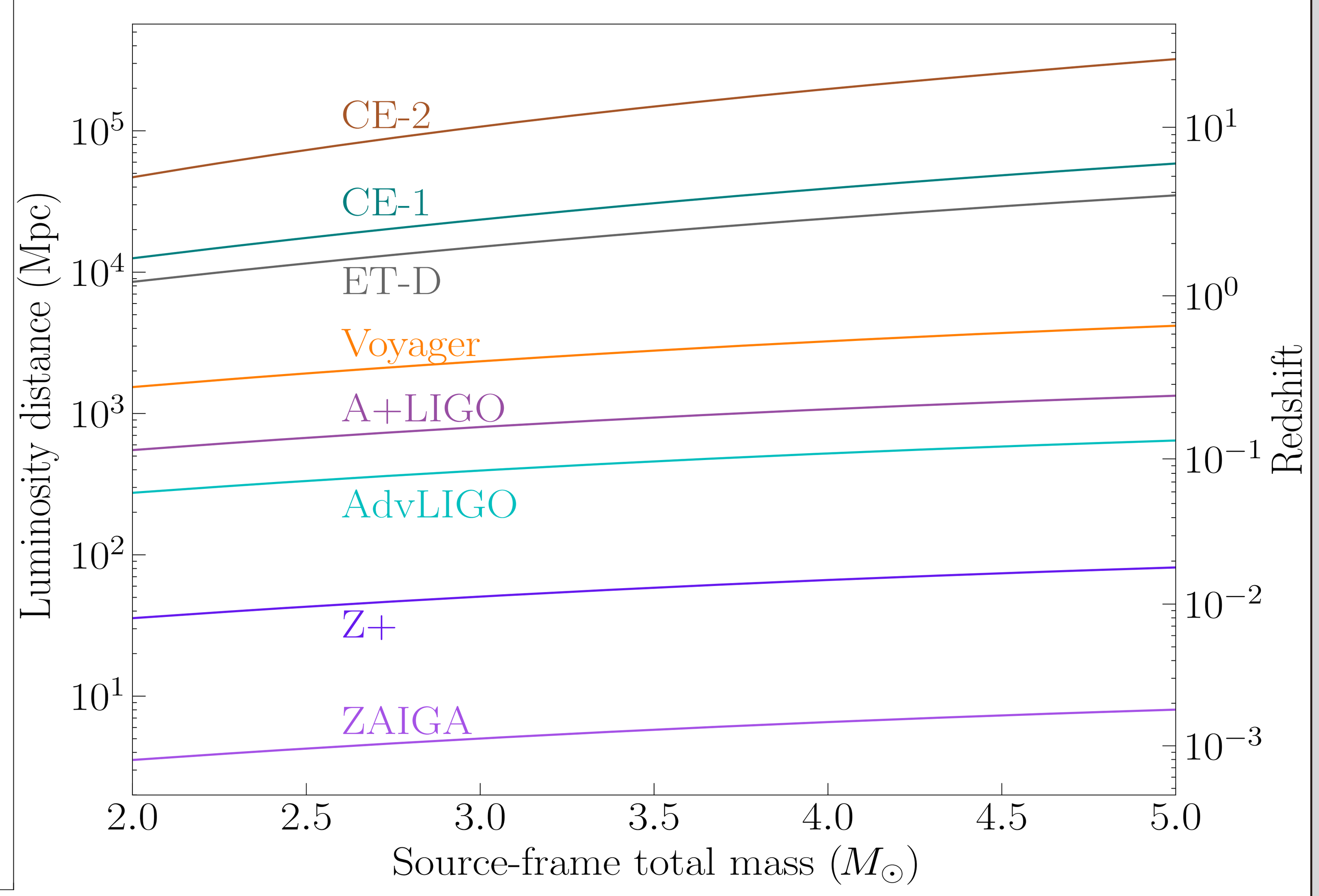
proposed Zhaoshan long-baseline Atom Interferometer Gravitation Antenna (ZAIGA), and its illustrative upgrade (Z+)

Advanced Laser Interferometer GW Observatory (AdvLIGO), with A+ upgrade (A+LIGO), a further update (Voyager)

Cosmic Explorer with two configurations (CE-1 and CE-2), Einstein Telescope with the latest configuration (ET-D)

An imaginary detector, Z+, whose strain sensitivity is improved by 10 times relative to ZAIGA





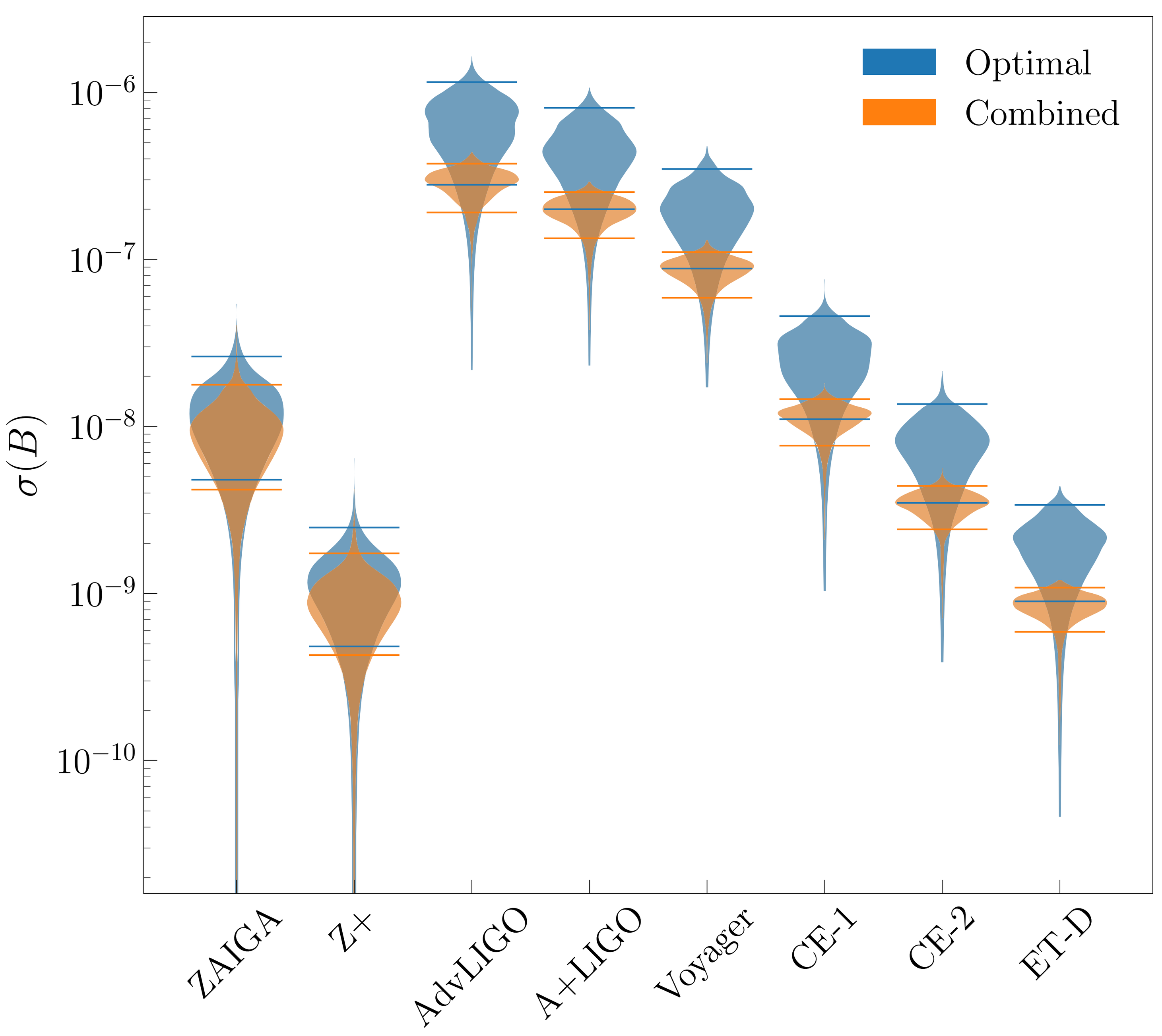
Result

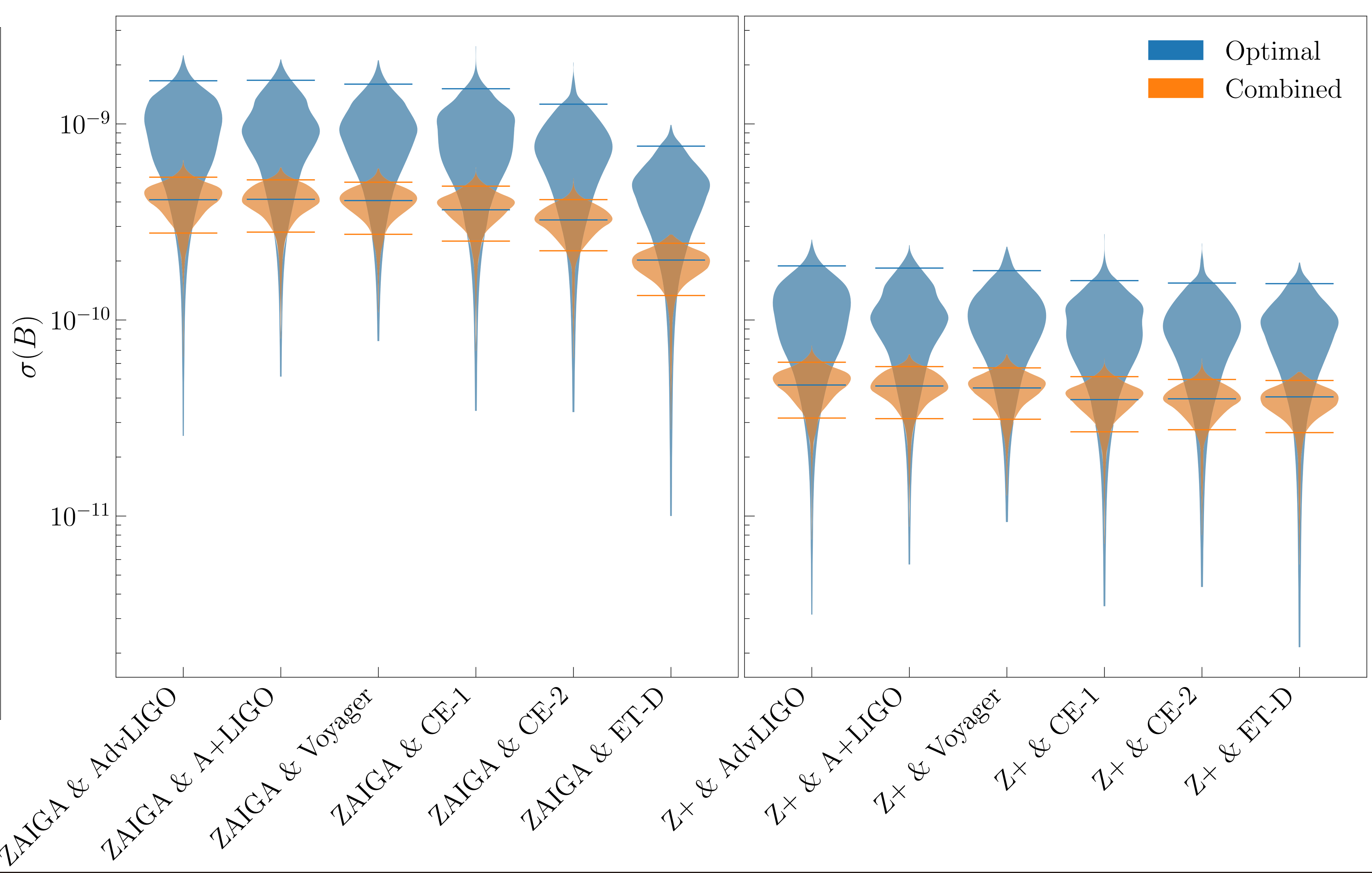
The modified GW flux due to the dipole raidation can be parametrized as $\dot{E}^{\rm GW} = \dot{E}^{\rm GR}\left[1 + B\left(\frac{m}{r}\right)^{-1}\right]$

The Fisher information matrix: $\Gamma_{ij} \equiv \left(\frac{\partial \tilde{h}(f)}{\partial \xi_i}\middle|\frac{\partial \tilde{h}(f)}{\partial \xi_j}\right)$ with the GW waveform $\tilde{h}(f)$ $\quad \mathscr{R}_0 = 1210\mathrm{Gpc}^{-3}\mathrm{yr}^{-1}$

$$\sigma(\xi_i) \geq \sqrt{(\Gamma^{-1})_{ii}}$$

Sample the population of binary neutron stars: $\frac{\mathrm{d}N_{\rm event}}{\mathrm{d}z} = \Delta T \times \frac{4\pi D^2_{\rm COM}(z)\mathscr{R}_0\, r(z)}{(1+z)H(z)}$ $\quad r(z) = \begin{cases} 1+2z, & z<1 \\ \frac{3}{4}(5-z), & 1 \leq z \leq 5 \\ 0, & z>5 \end{cases}$





Conclusion

Owing to its low accessible frequency and high sensitivity, ET can provide a tight bound on B alone, $\sigma(B) \sim 2\times 10^{-9}$

Even so, the constraint can still be improved to the level of $\mathcal{O}(10^{-10})$ from its joint observation with Z+.

References: M.-S. Zhan et al., Int. J. Mod. Phys. D 29, 1940005 (2020). E. Barausse et al., Phys. Rev. Lett. 116, 241104 (2016).