Contribution of Supermassive Black Hole Binary to nHz Gravitational Wave Background

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Abstract

We evaluate nHz gravitational wave background from supermassive black hole binaries using

- **Active Galactic Nuclei (AGN) luminosity function**
- **Dual AGN (a pair of AGN) fraction among all AGNs**

Our AGN-based model nicely reproduces the observed gravitational wave signals, reconciling with AGN observations.

Stochastic Gravitational Wave Background

- Stochastic Gravitational Wave Background (SGWB) is the integration of Gravitational Waves (GWs) whose primary sources are supermassive black hole binaries (SMBHBs).
- To reproduce the observed GW signals, **more $\geq 10^7 M_\odot$ supermassive black holes (SMBHs) are required than the observed population** (e.g., Sato-Polito+23,24).
- However, previous estimates were based on galaxy observables such as galaxy mass function.

What about using Active Galactic Nuclei (AGNs)?

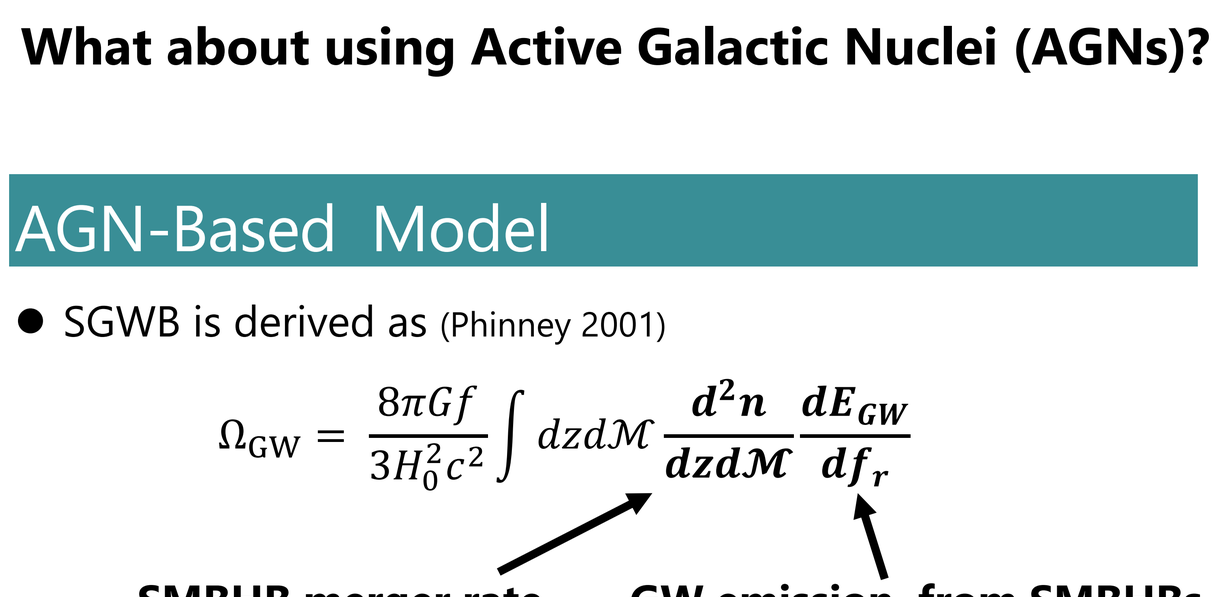
AGN-Based Model

- SGWB is derived as (Phinney 2001)

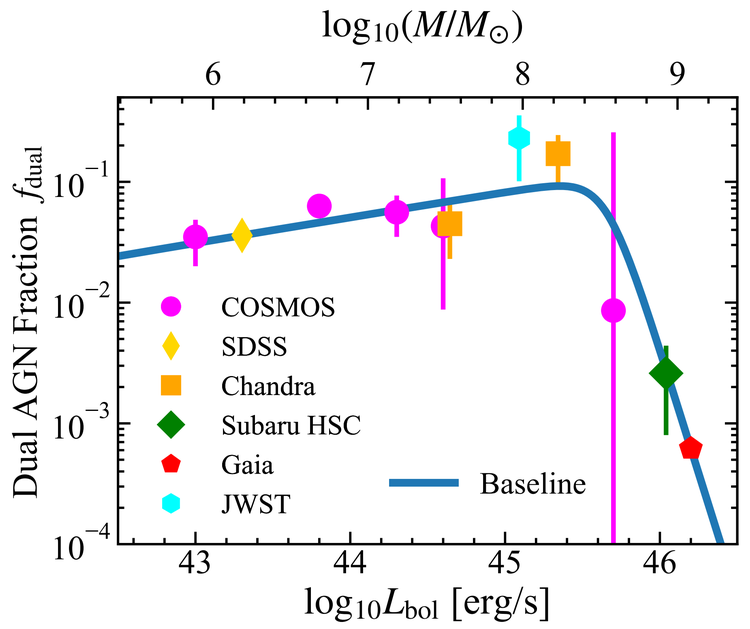
$$\Omega_{\rm GW} = \frac{8\pi G f}{3H_0^2 c^2} \int dz d\mathcal{M} \frac{\boldsymbol{d^2 n}}{\boldsymbol{dz d\mathcal{M}}} \frac{\boldsymbol{dE_{GW}}}{\boldsymbol{df_r}}$$

SMBHB merger rate **GW emission from SMBHBs**

- We adopt GW emission model including from the approaching phase to the post-merger phase.
- For the merger rate, we utilize SMBH mass function based on AGN luminosity function.



Dual AGN Fraction



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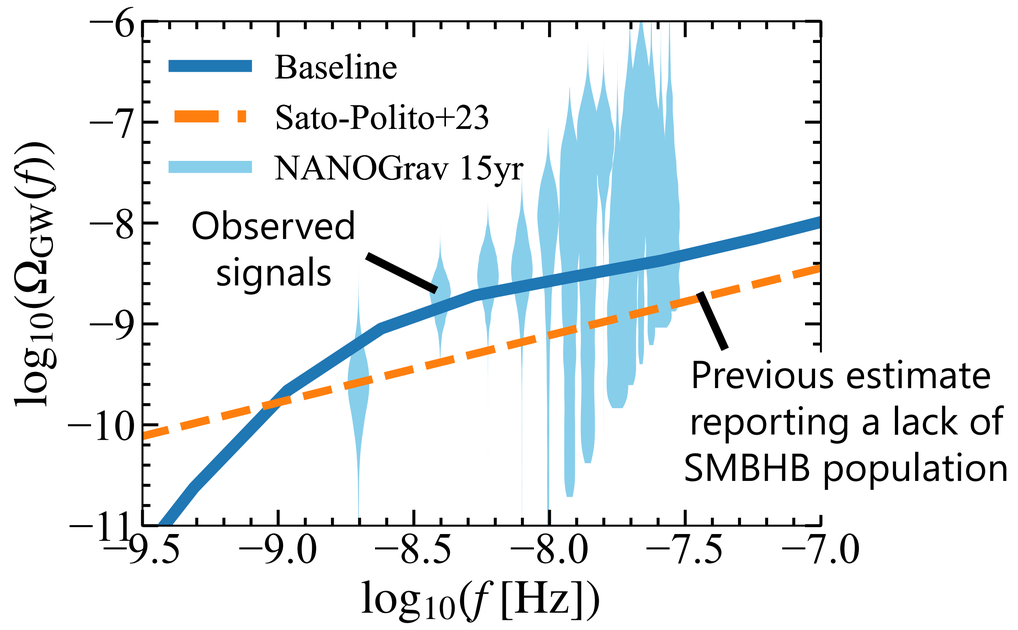
- Dual AGNs have been identified in recent studies. (e.g. Liu+11, Koss+12, Silverman+20, Shen+23, Perna+23, Li+24).
- Characteristic mass dependence in the dual AGN fractions is incorporated to calculate SGWB.

Result & Discussion



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- Our AGN-based model reproduces the observed signals.
- Mass-dependent dual AGN fractions affect the curvature of the SGWB spectrum.
- No need to add more massive SMBHs in contrast to the previous estimate.
- The main difference comes from the GW emission during the eccentric approaching phase, which is not included in the previous estimate.