GRB 211211A-like Events
and
How Gravitational Waves May Tell Their Origins

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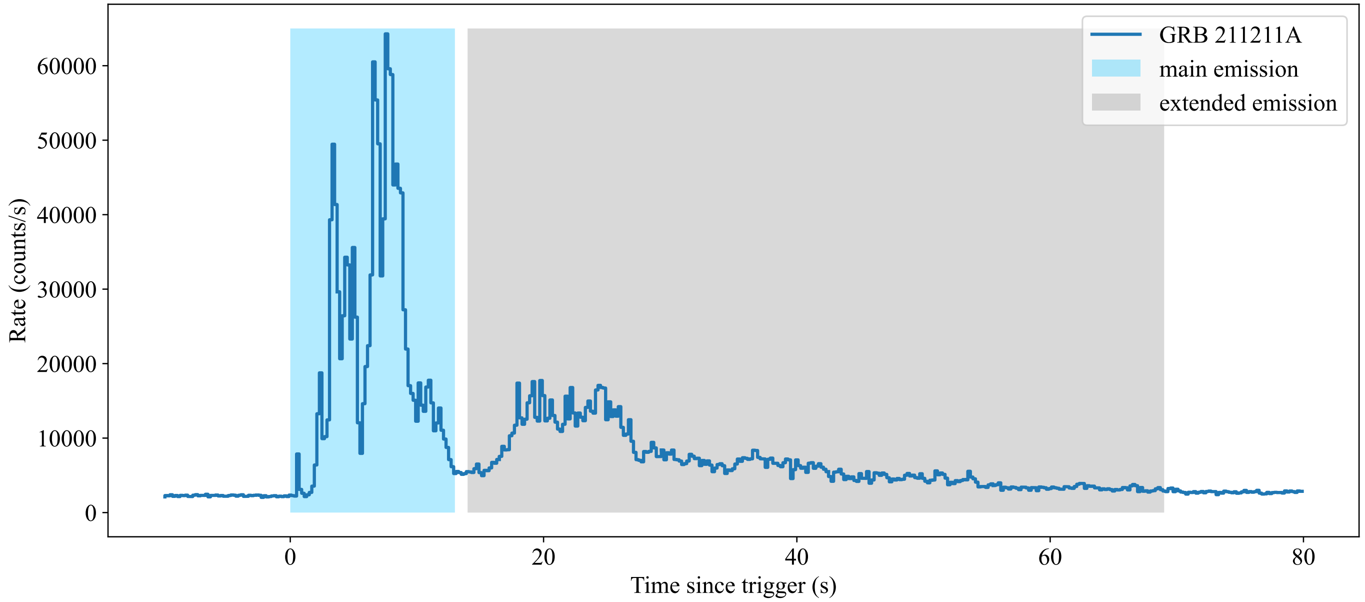
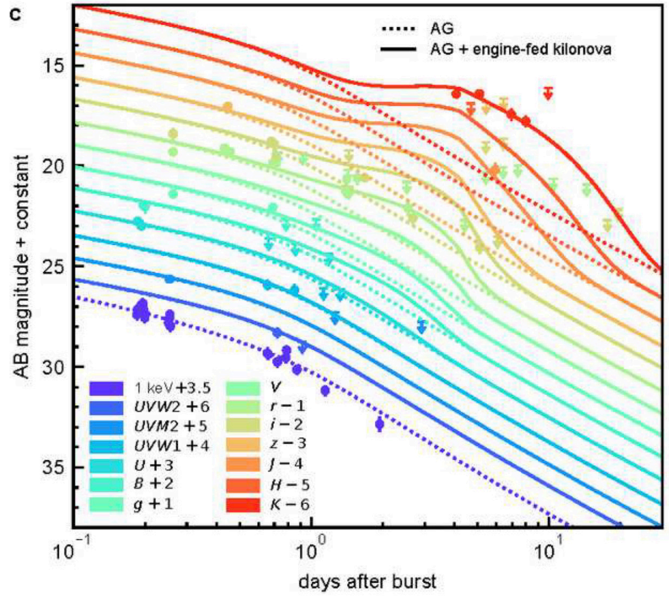
The Peculiar GRB 211211A





(*Jun Yang et al. 2022*)

long duration

kilonova evidence

NS-NS? NS-BH? NS-WD? Collapsar? …?

The Peculiar GRB 211211A

NS-BH interpretation

(*Jin-Ping Zhu et al. 2022)*

- a ~1.23 $M_{\odot}$ NS
- a ~ 8.21 $M_{\odot}$ BH
- an aligned spin of χ_{BH}~ 0.62
- formed an NS-first-born NSBH

NS-WD interpretation

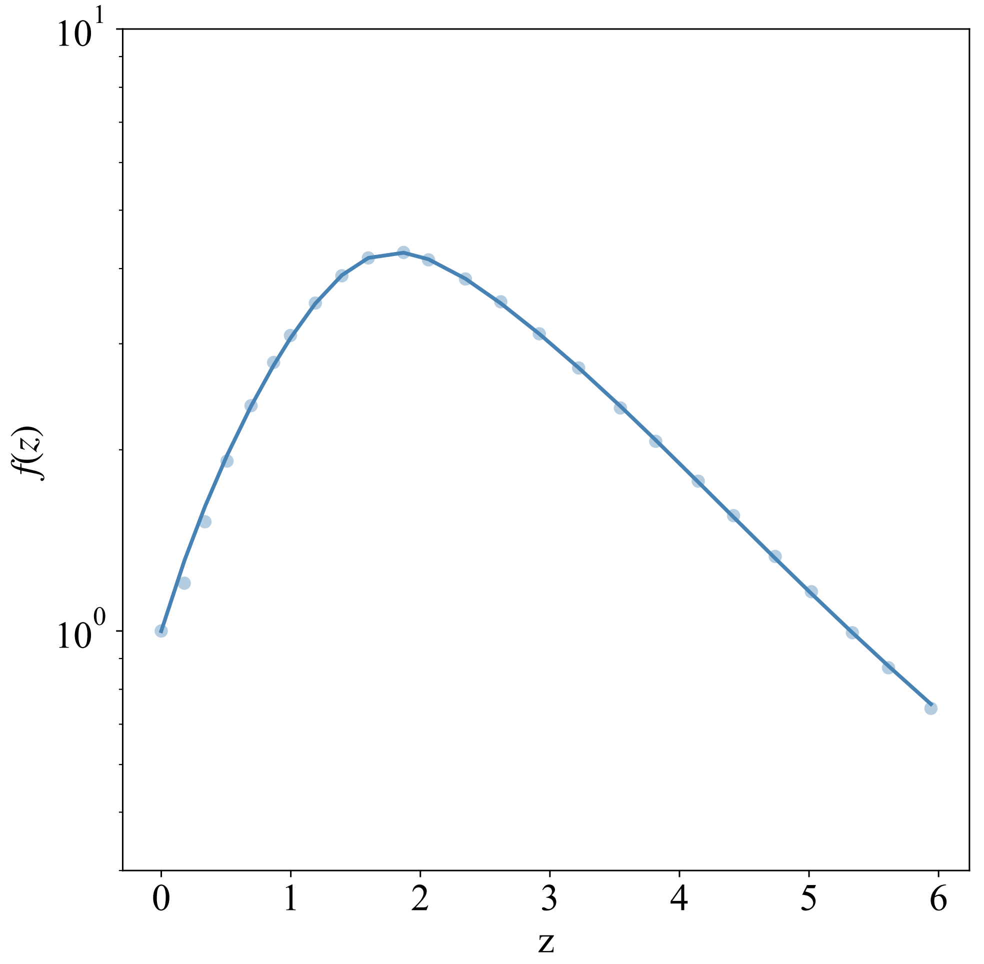
(*Jun Yang et al. 2022*)

- comparable masses
- WD close to the Chandrasekhar limit
- a millisecond post-merger magnetar engine
- WD ~ 1.3 $M_{\odot}$ and NS ~ 1.4 $M_{\odot}$

How Rare is GRB 211211A?

$$\underbrace{\frac{\overbrace{\Omega_{GBM}}^{\simeq 8\,sr}\ T_{GBM}}{4\pi}}\ \overbrace{\underline{\rho_{0,\mathrm{GRB\ 211211A}}}}^{\simeq 7\,yrs} V_{max} = \mathrm{N} \geq 1$$

$$V_{max} = \int_0^{z_{max}} \frac{\boxed{f(z)}}{1+z}\frac{dV(z)}{dz}\,dz$$



(derived from Eldrige et al. 2019)

How Rare is GRB 211211A?

$$\overbrace{\frac{\Omega_{GBM}}{4\pi}}^{\simeq 8\,sr}\,\overbrace{T_{GBM}}^{\simeq 7\,yrs}\,\underline{\rho_{0,\mathrm{GRB\,211211A}}}\,V_{max} = \mathrm{N} \geq 1$$

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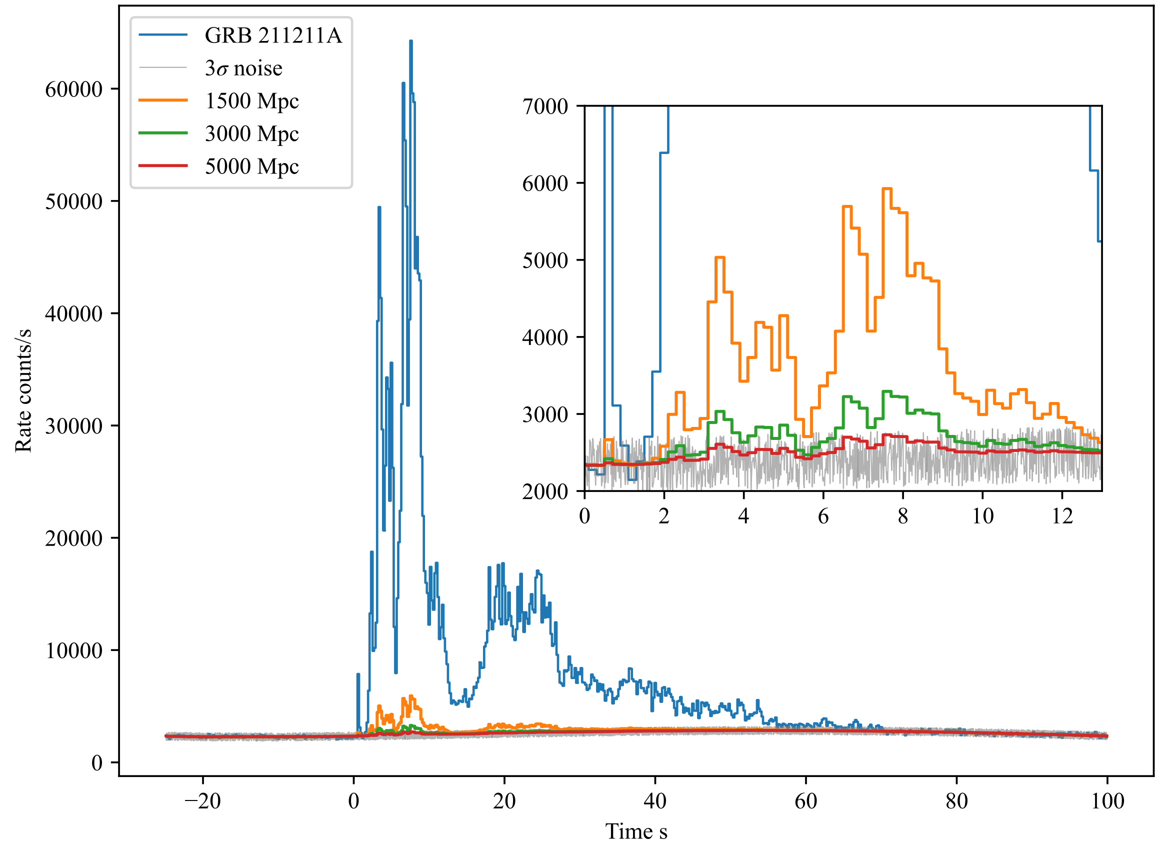


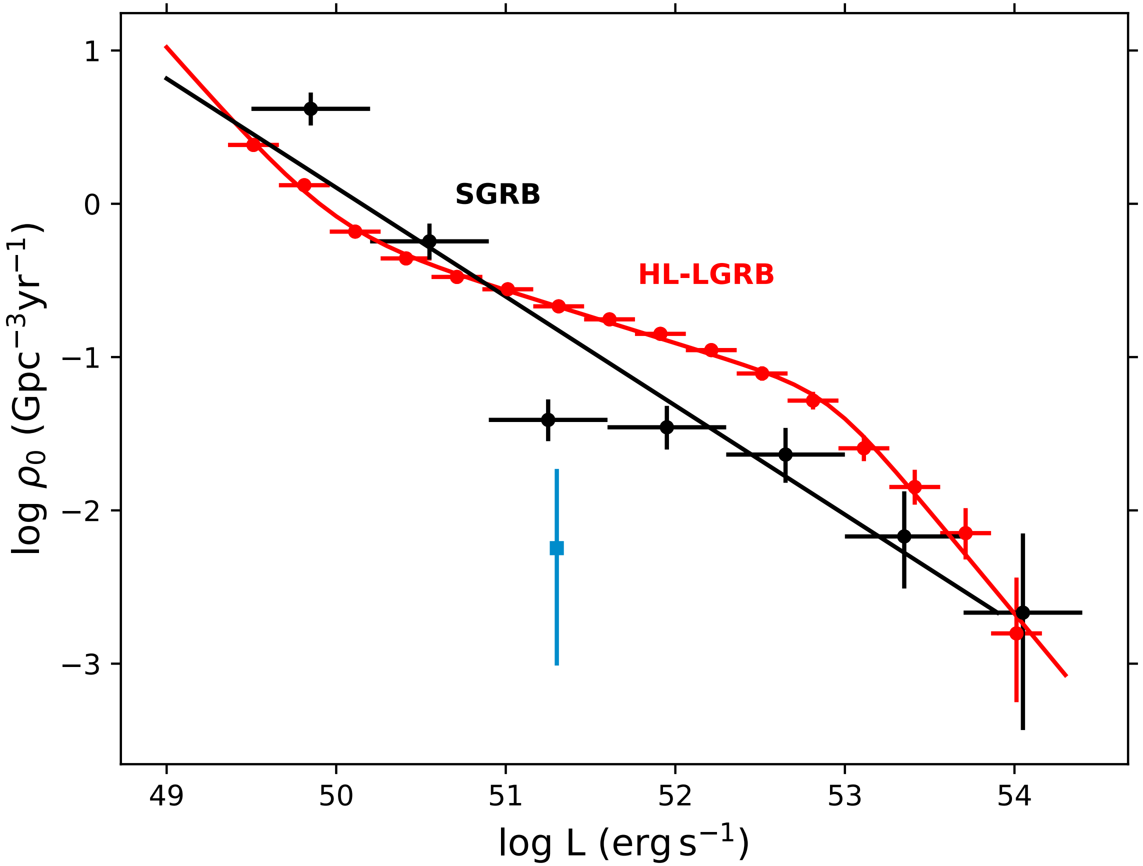
How Rare is GRB 211211A?

$$\overset{\simeq\, 8\, sr}{\Omega_{GBM}}\, \overset{\simeq\, 7\, yrs}{T_{GBM}} \over 4\pi$$

$$\frac{\Omega_{GBM}\, T_{GBM}}{4\pi} \underline{\rho_{0,\mathrm{GRB\ 211211A}}} V_{max} = \mathrm{N} \geq 1$$

$$V_{max} = \int_0^{z_{max}} \frac{f(z)}{1+z} \frac{dV(z)}{dz} dz$$

$$\boldsymbol{\rho_{0,\mathrm{GRB\ 211211A}} \simeq 5.67{\times}10^{-3} N\ Gpc^{-3} yr^{-1}}$$



How Rare is GRB 211211A?

From galactic source: BNS ~ 5000, NSWD ~ 6700

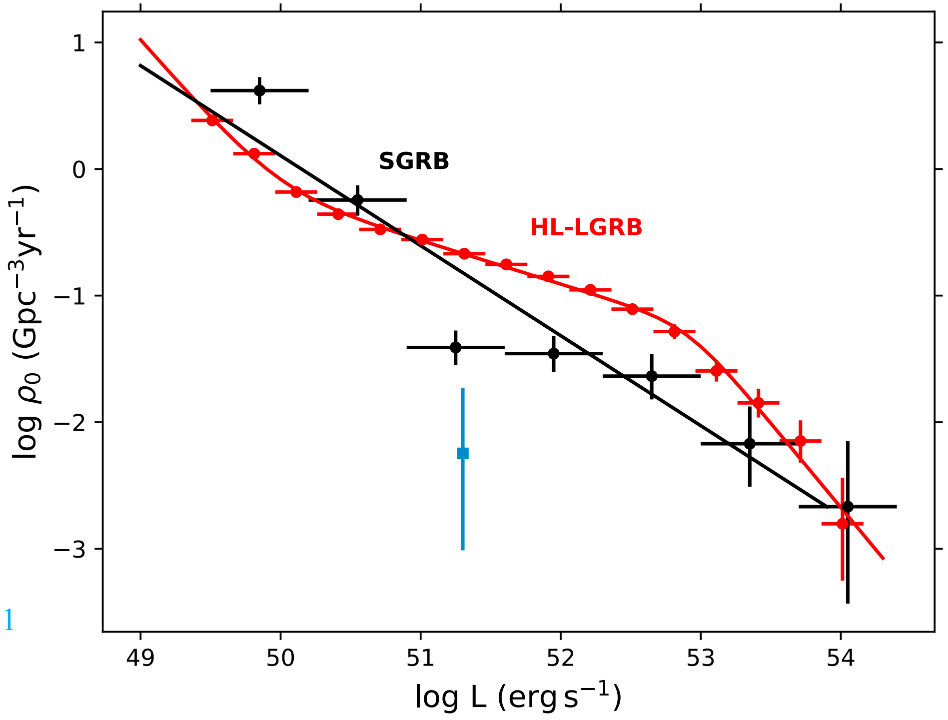
===> get a relative rate density factor $k \sim 1.34$

From SGRB data

===> get beamed BNS event rate density ρ_{BNS}

Assuming same beaming factor

===> NSWD event rate density $\rho_{\mathrm{NSWD}} = k \times \rho_{\mathrm{BNS}} = 1.3\ \mathrm{Gpc^{-3}\,yr^{-1}}$

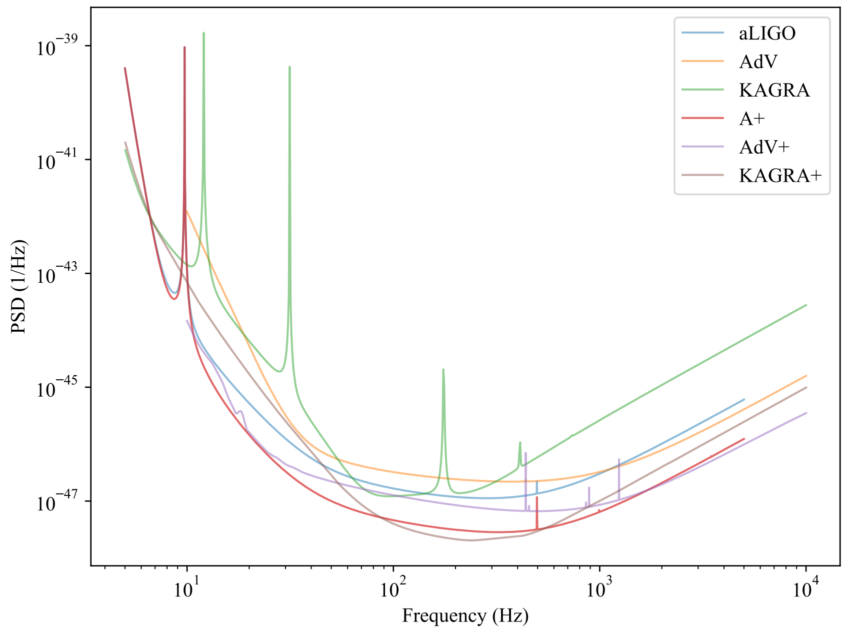


Fraction $f = \rho_{0,\mathrm{GRB211211A}} / \rho_{\mathrm{NSWD}} \sim N/307 \sim 3.26N$ ‰

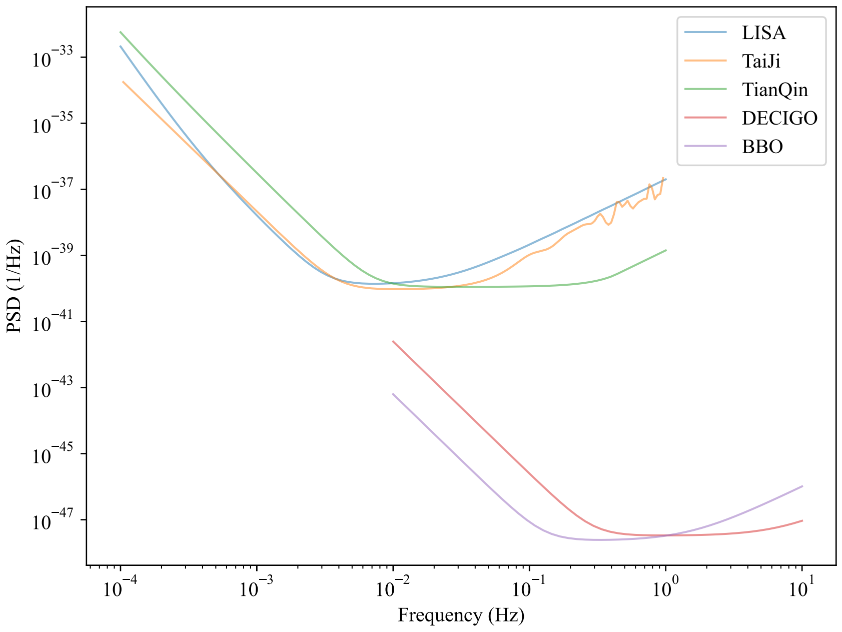
===> **only a few out of 307 NS-WD merger can make such a GRB**

Distinguish between GW Signals

Ground-based Detectors



Space-borne Detectors



Distinguish between GW Signals

NS-BH

inspiral phase (*TaylorF2*)

↓

inspiral-merger-ringdown

(*IMRPhenomNSBH*)

NS-WD

inspiral phase (*TaylorF2*)

↓

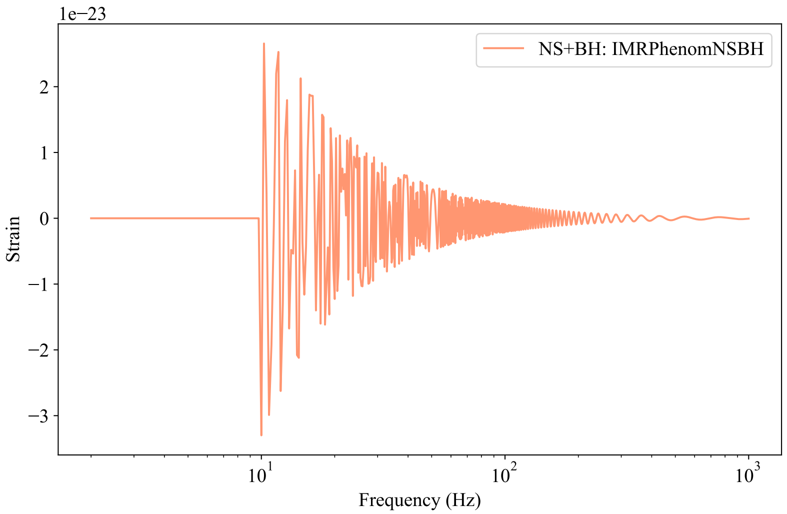
merger point (frequency)

↓

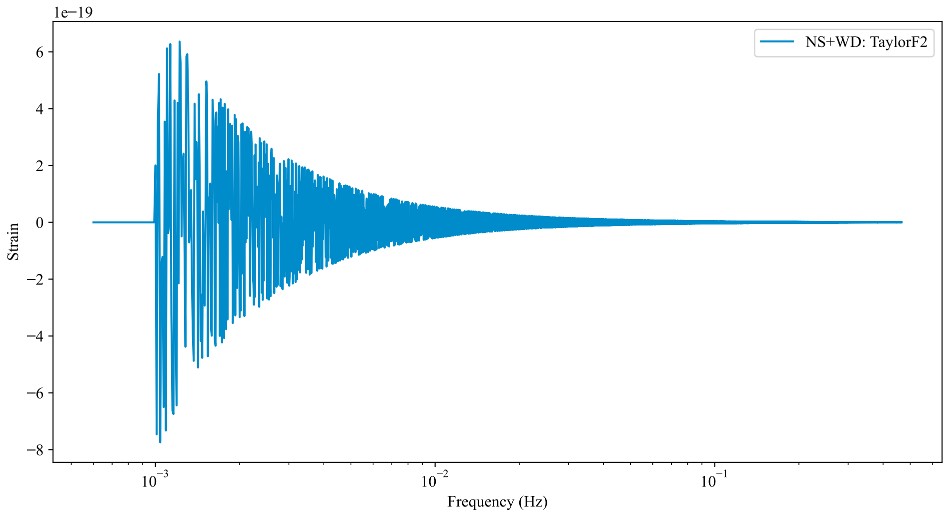
merger phase (unknown)

Distinguish between GW Signals

NS-BH



NS-WD



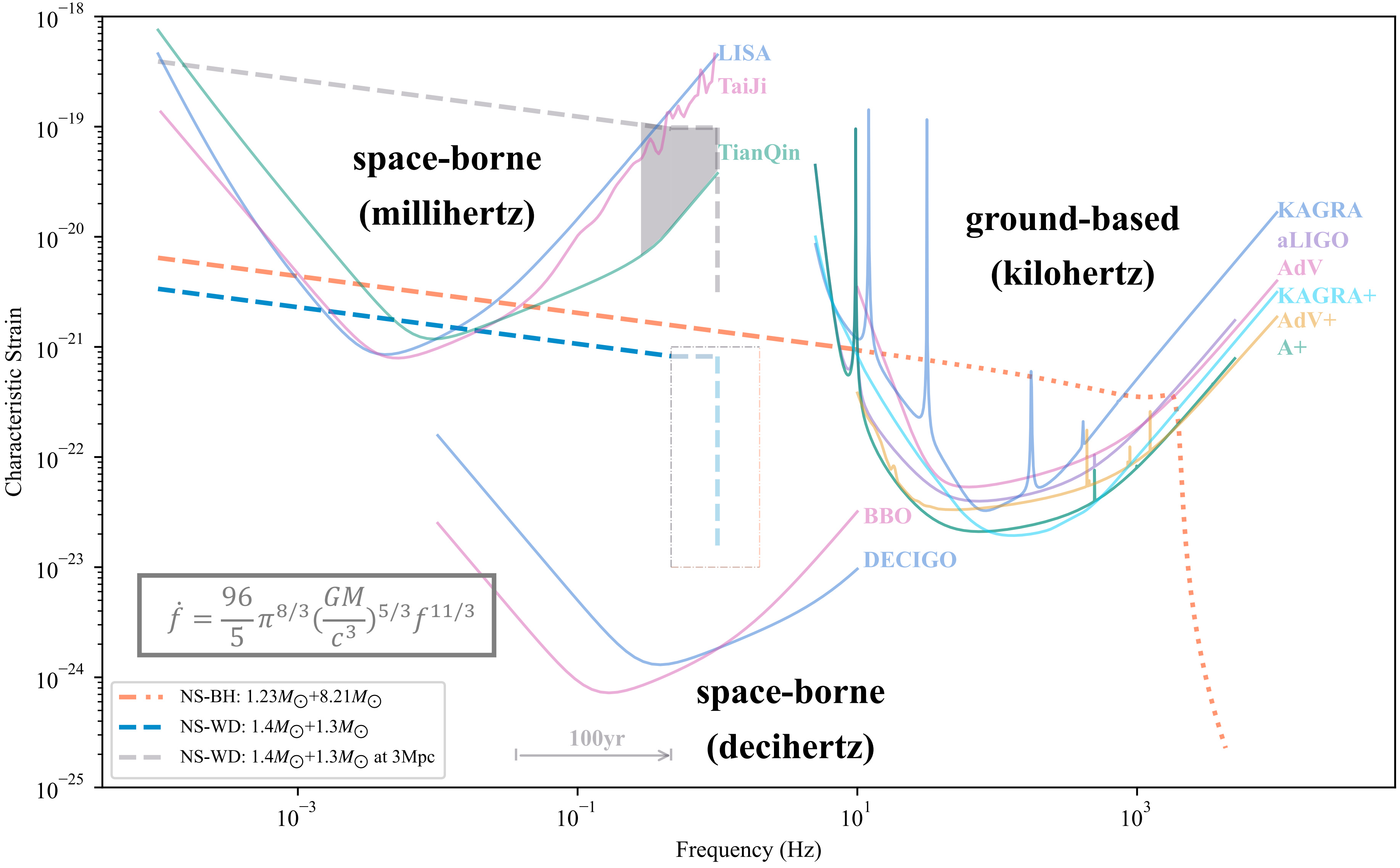
Detectability

obtain optimal signal-to-noise ratio (SNR) through matched filtering

$$\rho = 2\sqrt{\int_{f_{low}}^{f_{high}} \frac{|\tilde{h}(f)|^2}{S_n(f)}\, df} \xrightarrow[h_n(f) = \sqrt{f S_n(f)}]{h_c(f) = 2f|\tilde{h}(f)|} \rho = \sqrt{\int_{f_{low}}^{f_{high}} \left[\frac{h_c(f)}{h_n(f)}\right]^2 d(logf)}$$

in visualization: the area between the source and the detector curves on a log-log scale

Detectability

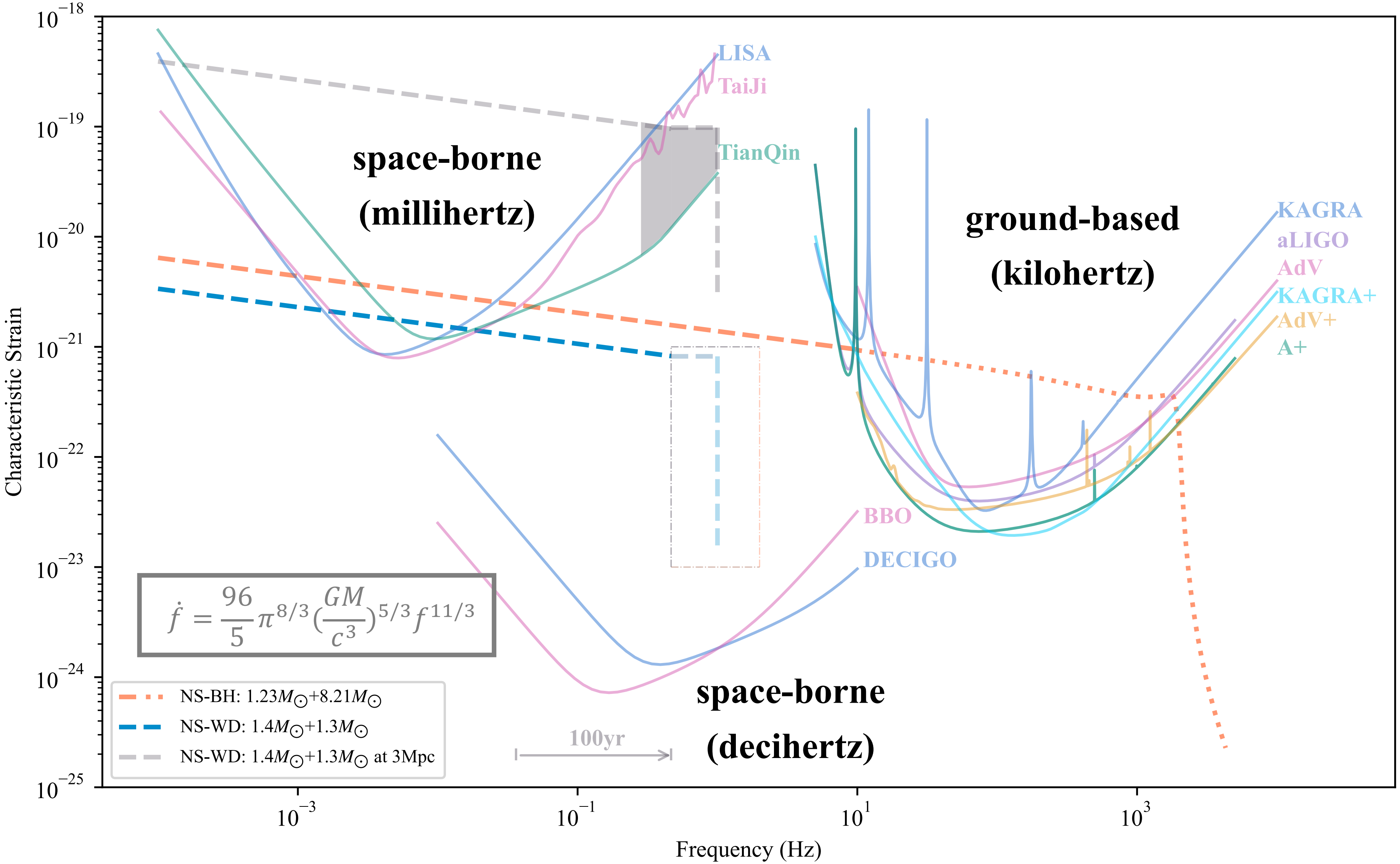


Detectability

Merger System	Detectors	Longevity	Distance (Mpc)	Range (Hz)	ρ	PSD Ref.
NS-BH	aLIGO	-	347.8	20-512	22.62	LIGO-T1800044-v5[a]
	AdV	-	347.8	20-512	16.15	LIGO-P1200087-v48[b]
	KAGRA	-	347.8	20-512	✅ 19.54	JGW-T1707038-v9[c]
	A+	-	347.8	20-512	43.35	LIGO-T1800042-v5[d]
	AdV+	-	347.8	20-512	29.52	LIGO-P1200087-v48[e]
	KAGRA+	-	347.8	20-512	38.27	JGW-T1809537-v6[f]
NS-WD	BBO	$\sim$ 5 years	347.8	$(1.03 - 4.66) \times 10^{-1}$	✅ 1432.36	Yagi & Seto (2011)
	DECIGO	$\sim$ 5 years	347.8	$(1.03 - 4.66) \times 10^{-1}$	635.62	
	LISA	$\sim$ 4 years	347.8	$(3.63 - 3.70) \times 10^{-2}$	4.55×10^{-2}	Robson et al. (2019)
			$\boxed{1.98}$		$\boxed{8}$	
	TaiJi	$\sim$ 5 years	347.8	$(4.58 - 4.79) \times 10^{-2}$	8.92×10^{-2}	Ruan et al. (2020)
			$\boxed{3.83}$		$\boxed{8}$	
	TianQin	2 $\times$ (3 months) each year	347.8	$(2.84 - 4.66) \times 10^{-1}$	7.18×10^{-2}	Hu et al. (2018)
			$\boxed{3.10}$		$\boxed{8}$	

For millihertz space-borne detectors to detect the signal, GRB 211211A would have to be much closer, e.g., at a distance of around **3 Mpc**.

Detectability



THANK YOU