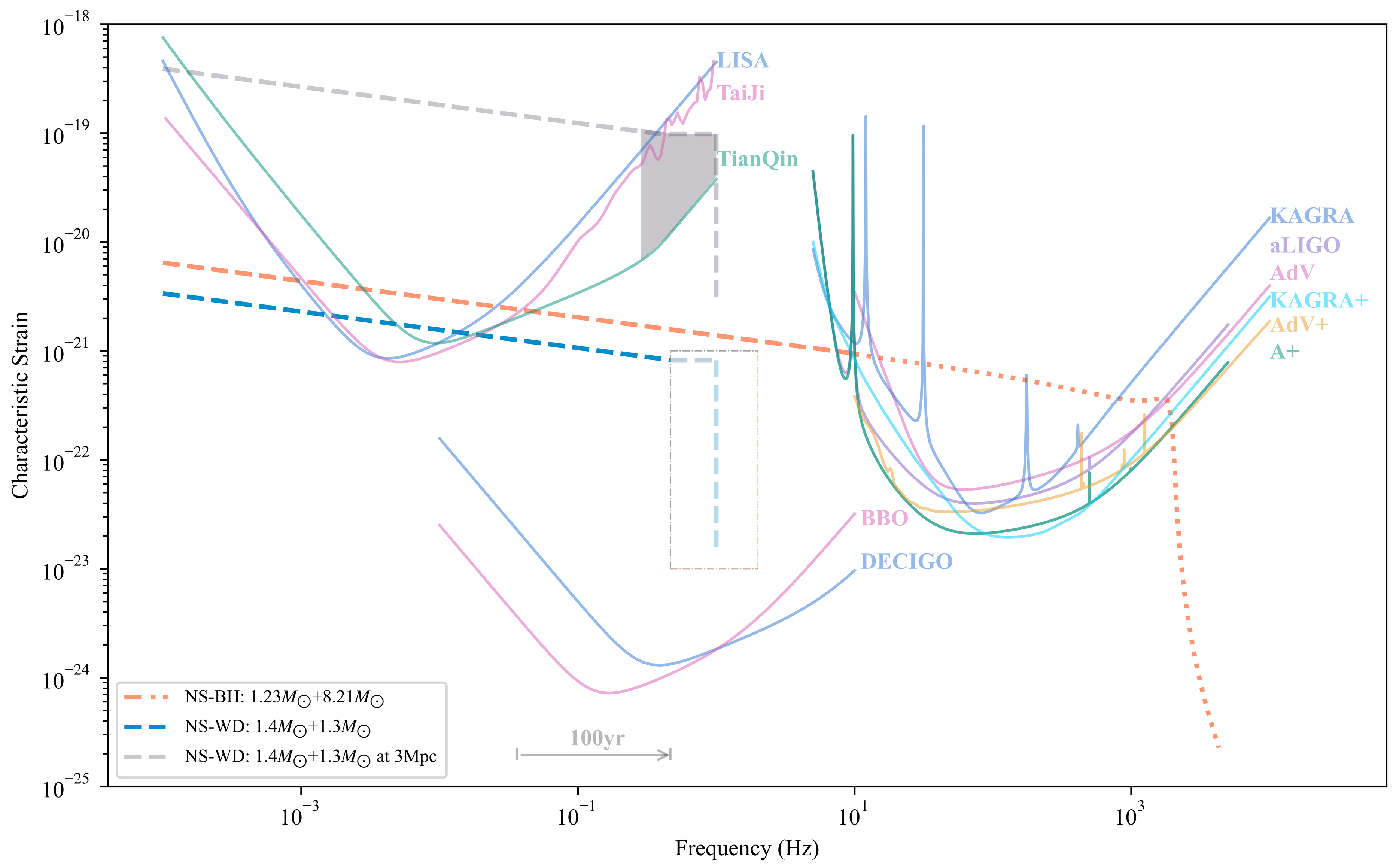
GRB 211211A-like Events and How Gravitational Waves May Tell Their Origins

Yi-Han Iris Yin, Bin-Bin Zhang, Hui Sun, Jun Yang, Yacheng Kang, Lijing Shao, Yu-Han Yang, Bing Zhang

School of Astronomy and Space Science, Nanjing University, Nanjing 210093, China
School of Physics, Nanjing University, Nanjing 210093, China
School of Astronomy and Space Science, Nanjing University, Nanjing 210093, China
Key Laboratory of Modern Astronomy and Astrophysics (Nanjing University), Ministry of Education, China
Purple Mountain Observatory, Chinese Academy of Sciences, Nanjing, 210023, China
Key Laboratory of Space Astronomy and Technology, National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China
Department of Astronomy, School of Physics, Peking University, Beijing 100871, China
Kavli Institute for Astronomy and Astrophysics, Peking University, Beijing 100871, China
National Astronomical Observatories, Chinese Academy of Sciences, Beijing 100012, China
Department of Physics, University of Rome "Tor Vergata", via della Ricerca Scientifica 1, I-00133 Rome, Italy
Nevada Center for Astrophysics, University of Nevada Las Vegas, NV 89154, USA
Department of Physics and Astronomy, University of Nevada Las Vegas, NV 89154, USA

Predicted GW Detections



Detection of GRB 211211A GW events using both ground-based and spaceborne detectors. *Orange dashed and dot lines:* the characteristic strain for the case of a NS-BH merger. *Blue dashed lines:* the characteristic strain for the case of a NS-WD merger. *Gray dashed line:* the characteristic strain for the case of a NS-WD merger at 3 Mpc. *Colored solid curves:* the characteristic noise strain of different GW detectors. *Color-filled blocks:* the detecting frequency range for the case of a NS-WD merger at 3 Mpc with TianQin. The gray arrow denotes the duration of the inspiral phase of the NS-WD system, which corresponds to the time taken for the frequency to change from 3.63×10^{-2} Hz to 4.66×10^{-1} Hz.

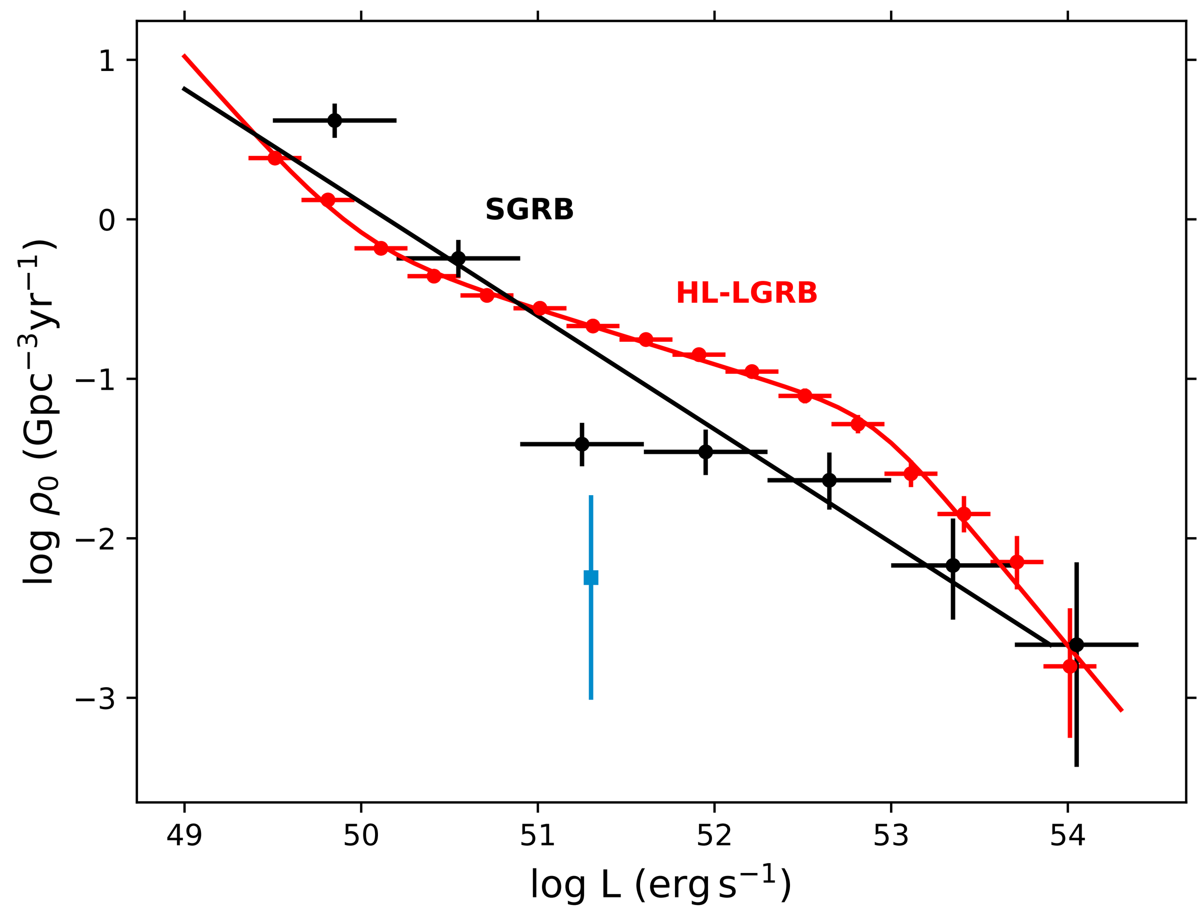
NSBH & NSWD Mergers S/Ns

Sys.	Det.	D.(Mpc)	Range(Hz)	S/N
NSBH	aLIGO	347.8	$20-512$	22.62
NSBH	AdV	347.8	$20-512$	16.15
NSBH	KAGRA	347.8	$20-512$	19.54
NSBH	A+	347.8	$20-512$	43.35
NSBH	AdV+	347.8	$20-512$	29.52
NSBH	KAGRA+	347.8	$20-512$	38.27
NSWD	BBO	347.8	$(1.03-4.66)\times 10^{-1}$	1432.36
NSWD	DECIGO	347.8	$(1.03-4.66)\times 10^{-1}$	635.62
NSWD	LISA	347.8	$(3.63-3.70)\times 10^{-2}$	4.55×10^{-2}
NSWD	LISA	1.98	$(3.63-3.70)\times 10^{-2}$	8
NSWD	Taiji	347.8	$(4.58-4.79)\times 10^{-2}$	8.92×10^{-2}
NSWD	Taiji	3.83	$(4.58-4.79)\times 10^{-2}$	8
NSWD	TianQin	347.8	$(2.84-4.66)\times 10^{-1}$	7.18×10^{-2}
NSWD	TianQin	3.10	$(2.84-4.66)\times 10^{-1}$	8

* The results do not consider the impact of confusion noise nor the matter and tidal effects in NS-WD mergers.

With LIGO's designed sensitivity, the NS-BH merger that caused GRB 211211A would be detectable with a significant S/N. On the other hand, the NS-WD binary would also generate a notable S/N during the inspiral phase with decihertz spaceborne detectors, such as DECIGO and BBO, but detecting such a system with millihertz spaceborne detectors like LISA, Taiji, and TianQin would require the event to be closer, at approximately 3 Mpc distance.

How Rare Is GRB 211211A?



Our research reveals an event rate density of $\gtrsim 5.67^{+13.04}_{-4.69} \times 10^{-3}$ Gpc^{-3} yr^{-1} for GRB 211211A-like GRBs, which, assuming GRB 211211A is the only example of such a burst, is significantly smaller than that of typical long- and short-GRB populations.

We found that only a small portion of the NS-WD system can produce such a burst. This event rate density can be regarded as a conservative lower limit for a long GRB with an NS-WD origin, suggesting that similar events may already be present in the archival data.

Despite the fact that there is a lack of coincident GW and long-GRB detection reported in Wang et al. (2022), where they searched for signals from BNS or NS-BH mergers and long GRBs from 4-OGC and the Fermi-GBM/Swift-BAT catalog, our study highlights the potential for further investigation of coincident GW and long-GRB signals from NS-WD mergers with upcoming GW detectors.

Corresponding Author: bbzhang@nju.edu.cn