Prospects for detecting exoplanets around double white dwarfs with LISA and Taiji

Yacheng Kang, Chang Liu, Lijing Shao

DoA & KIAA, Peking University

Astron. J. (accepted) arXiv:2108.01357

1. Abstract

★Recently, **Tamanini & Danielski (2019)** discussed the possibility to detect circumbinary exoplanets (CBPs) orbiting double white dwarfs (DWDs) with the Laser Interferometer Space Antenna (LISA). Extending their methods and criteria, we discuss the prospects for detecting exoplanets around DWDs **not only by LISA, but also by Taiji**, a Chinese space-borne gravitational-wave (GW) mission that has slightly better sensitivity at low frequencies.

★We first explore how **different binary masses and mass ratios** affect the abilities of LISA and Taiji to detect CBPs. Second, for certain **known detached DWDs** with high signal-to-noise ratios, we quantify the possibility of CBP detections around them. Third, based on the DWD population obtained from the Mock LISA Data Challenge, we present basic assessments of the **CBP detections in our Galaxy** during a 4 year mission time for LISA and Taiji.

★We discuss the **constraints on the detectable zone** of each system, as well as the distributions of the inner/outer edge of the detectable zone. Given the DWD population, we further inject two different planet distributions with an occurrence rate of 50% and **constrain the total detection rates**. We briefly discuss the prospects for **detecting habitable CBPs around DWDs** with a simplified model. These results can provide helpful inputs for upcoming exoplanetary projects and help analyze planetary systems after the common envelope phase.

2. Method

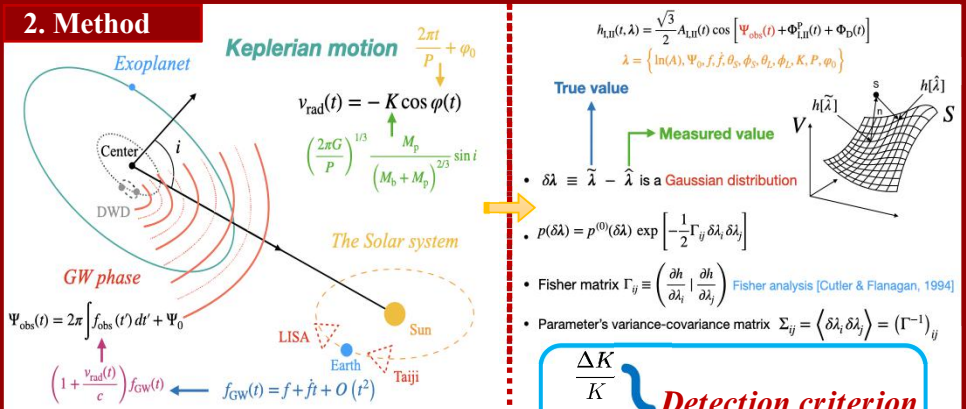


Figure 1. Illustration of changes on the observed GW frequency through the Doppler effect

3. Detecors

LISA

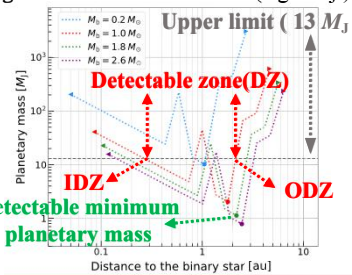
ESA-led: [Amaro-Seoane et al., 2017]

VS

Taiji

China: [Ziren Luo et al., 2020]

Figure 2. Selection functions (e.g. Taiji)



4. Results

For known DWDs: **< 13 M_J ?**

Source	a_{min} [au]	Taiji M_p^{min} [M_J]	Taiji IDZ [au]	Taiji ODZ [au]	Taiji SNR	LISA M_p^{min} [M_J]	LISA IDZ [au]	LISA ODZ [au]	LISA SNR
ZTF J153932.16+502738.8	1.53	1.39	0.20	2.20	124.51	2.11	0.32	2.12	81.89
SDSS J065133.34+284423.4	1.79	2.34	0.31	2.04	117.18	2.95	0.49	2.00	92.83
SDSS J093506.92+441107.0	2.03	4.76	0.73	2.21	139.66	9.50	1.40	2.12	70.02
SDSS J232230.20+050942.06	1.59	10.47	1.35	1.66	70.72	21.27	-	-	34.82

Table 1. Possible detections of CBPs around known DWDs

For MLDC Round 4: **SNR ≥ 10**

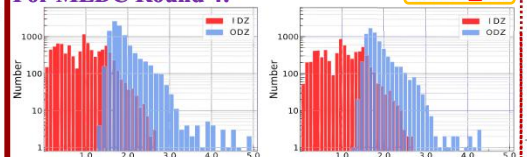


Figure 3. Distributions of IDZ and ODZ for ***promising systems***
Left: Taiji (9053) Right: LISA (6718)

For different CBP models: **OR: 50%**

Case A: $\log \mathcal{U}_a(0.1-200\ \mathrm{au})$; $\mathcal{U}_{M_p}(1M_\oplus - 0.08M_\odot)$
※ 40 (0.16%) for Taiji
※ 16 (0.10%) for LISA

Case B: $\mathcal{U}_a(0.1-200\ \mathrm{au})$; $\mathcal{U}_{M_p}(1M_\oplus - 0.08M_\odot)$
※ 2 (0.008%) for Taiji
※ 0 (0%) for LISA

Note: ***Total*** *detached DWDs (4-year)*
25016 (15903) for Taiji (LISA)

For habitable CBPs: **Fixed luminosity**

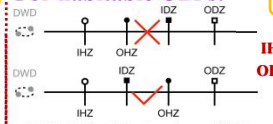


Table 2. Possible detections of CBPs around ***promising systems***

Detector	Clouds 0% IHZ [au]	Clouds 0% OHZ [au]	Clouds 50% IHZ [au]	Clouds 50% OHZ [au]	Clouds 100% IHZ [au]	Clouds 100% OHZ [au]
Taiji	3 (0.033%)	5 (0.055%)	13 (0.14%)			
LISA	1 (0.015%)	1 (0.015%)	3 (0.45%)			

5. Conclusions

I. Complementary to electromagnetic methods;
II. Comparisons between Taiji (better) and LISA;
III. Possible detections (around known DWDs; in the whole Galaxy; habitable CBPs).

6. References

- Danielski, C.et al., 2019,AstronAstrophys., 632, A113
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