



LGWA
LUNAR GRAVITATIONAL
WAVE ANTENNA



UNIVERSITÀ
DEGLI STUDI
DI PADOVA



Dipartimento
di Fisica
e Astronomia
Galileo Galilei

Observation of DWDs as SNIa progenitors using the Lunar GW Antenna

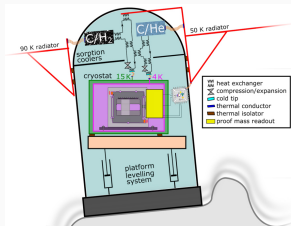
An Extraordinary Journey into the Transient Sky

April 4, 2025

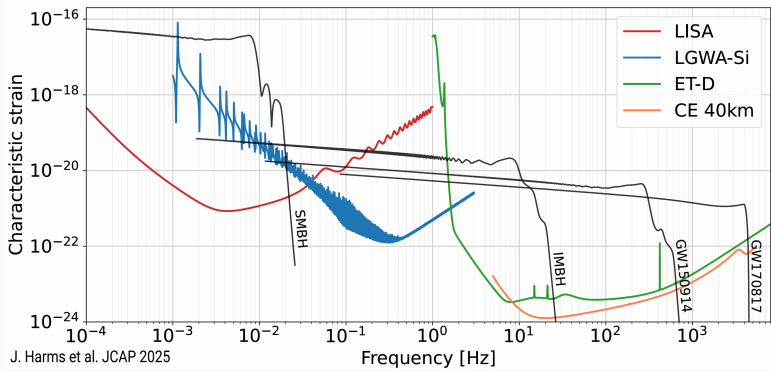
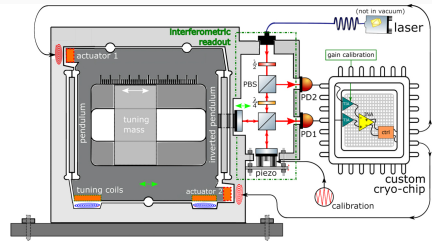
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The Lunar Gravitational-Wave Antenna

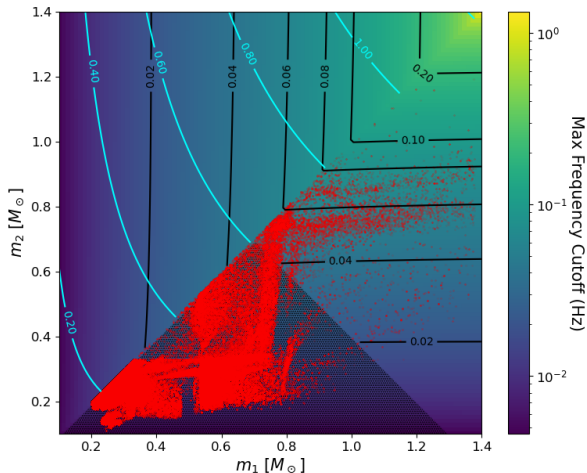


J. V. van Heijningen et al. J. Appl. Phys. 2023



J. Harms et al. JCAP 2025

DWD population characteristics



Simulated population

sub/super-Chandrasekhar
Super-Ch branch

Merging frequency

Roche overflow
0.04 - 0.2 Hz

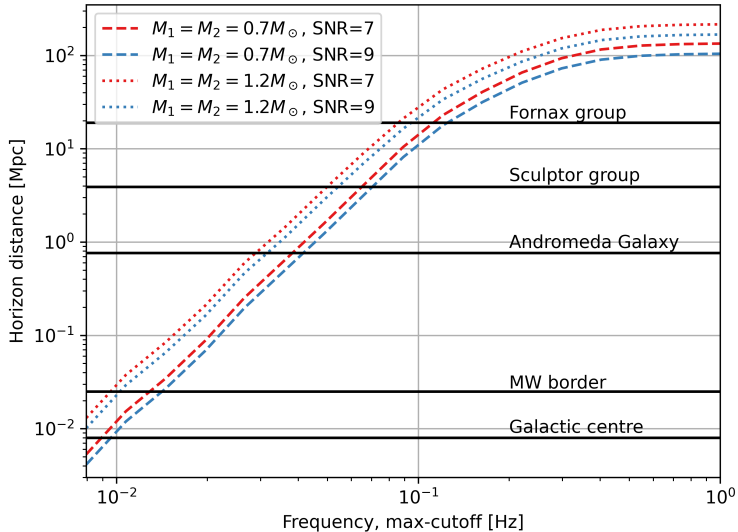
$$\text{SNR}^2 = 4 \int_{f_{\min}}^{f_{\text{cutoff}}} \frac{|\tilde{h}(f)|^2}{S_n(f)} df$$

Chirp mass

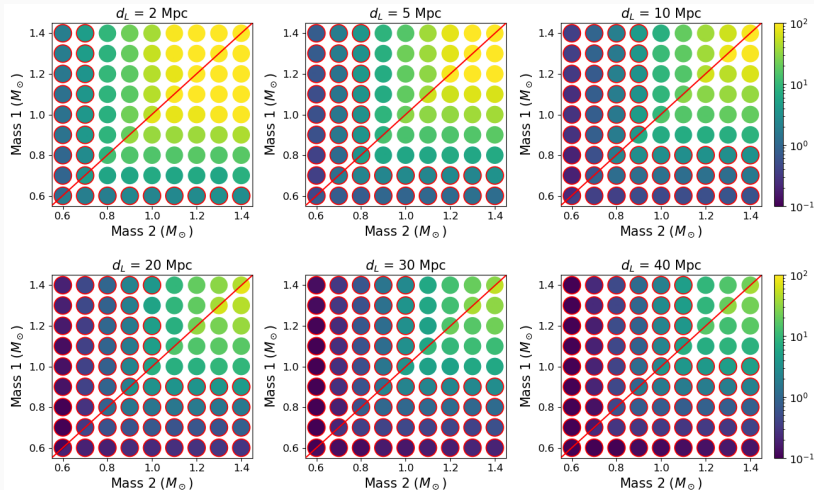
Evolution timescale

$$t_m(f) = \frac{\frac{5c^5}{256} f^{-\frac{8}{3}}}{G^{\frac{5}{3}} \mathcal{M}^{\frac{5}{3}} \pi^{\frac{8}{3}}}$$

Observability



Observability



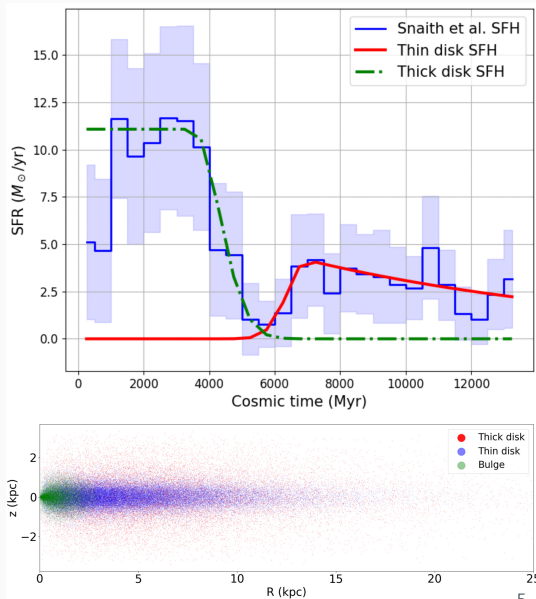
Roche cutoff, averaged (best) over (under) the diagonal.

SNR threshold = 5

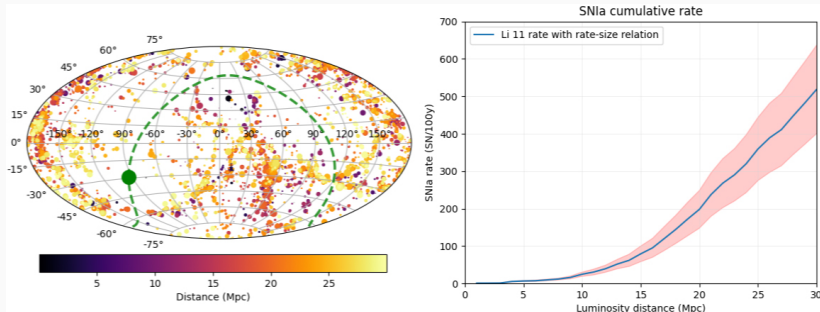
DWD population simulation

Milky Way:

- Evolutive simulation (software SeBa, Portegies Zwart Verbunt 1996; Toonen et al. 2012)
- Multi-component model
- Star Formation Histories
- Total abundance from SNIa rate ($r = (5.4 \pm 1.2) \cdot 10^{-3} \text{ SN yr}^{-1}$)



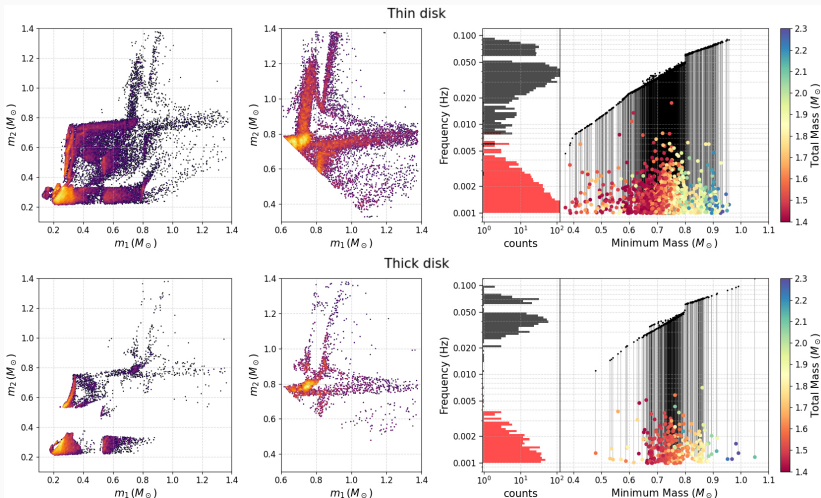
DWD population simulation



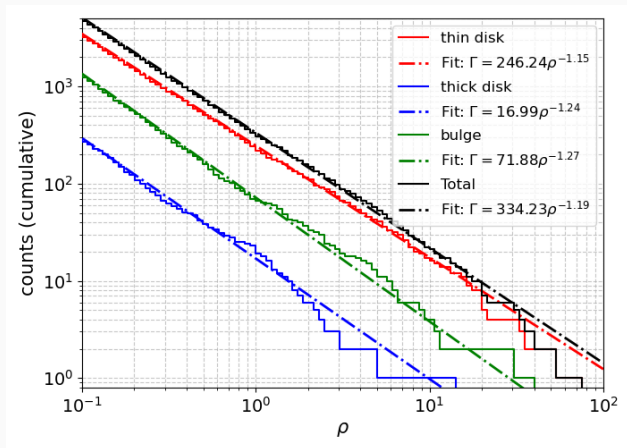
Extragalactic population:

- HyperLeda catalogue up to 30 Mpc
- SN Ia rate from rate-size relation (Li et al. 2011)
- Incompleteness ($\approx 20\%$)

DWD population simulation



MW analysis: spiralling DWDs



Software LEGWORK
Wagg et al. 2022a,b

Cumulative (SNR)
distribution

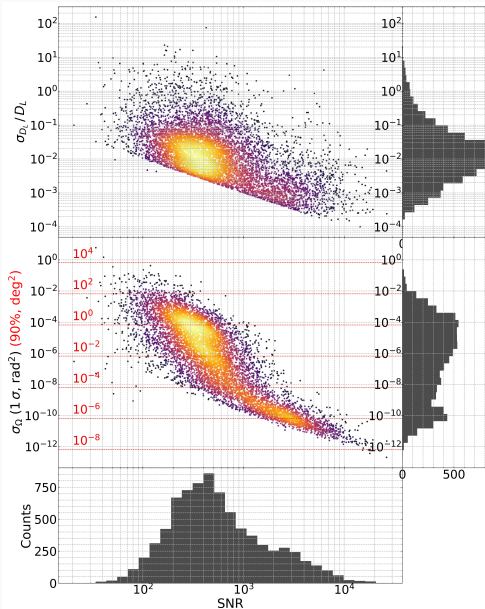
$$\rho_t = 5 \implies N = 50$$

$$\rho_t = 7 \implies N = 33$$

$$\rho_t = 9 \implies N = 25$$

Visible in LISA band

MW analysis: merging DWDs



Thin disk, super-Ch

Software GWFish

Dupletsa et al. 2023

Fisher matrix method

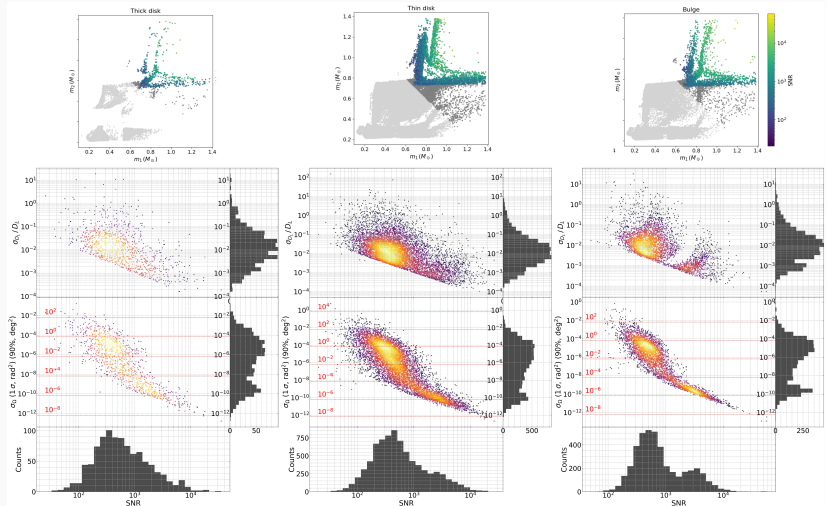
Localization capabilities

SNR, rel. err. on luminosity

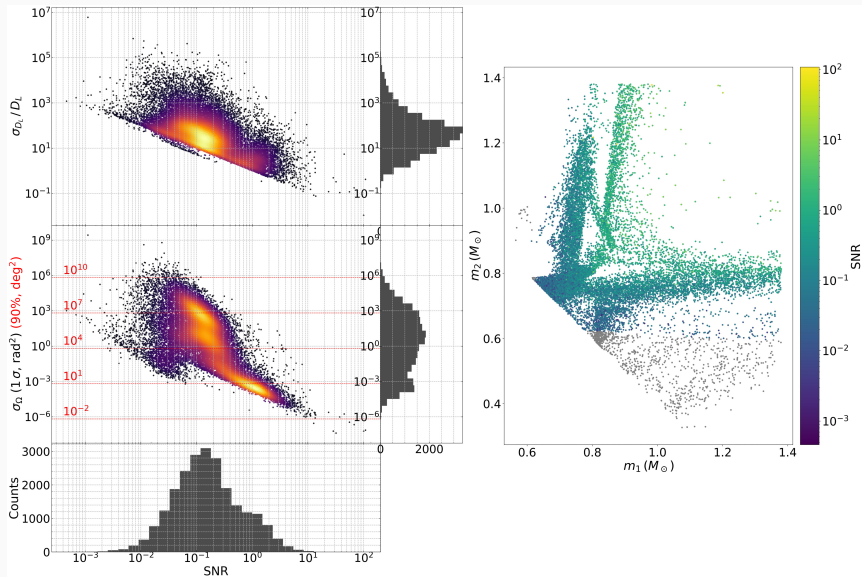
distance, err. on sky location

near LGWA maximum
sensitivity

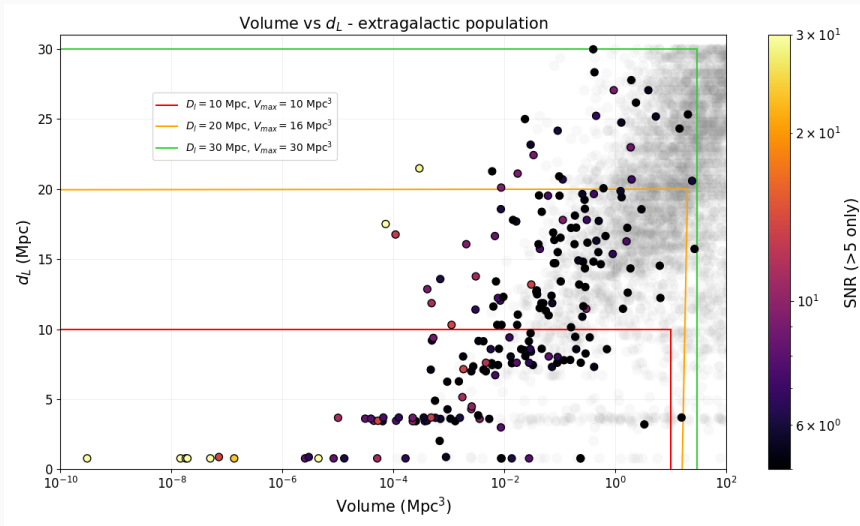
MW analysis: merging DWDs



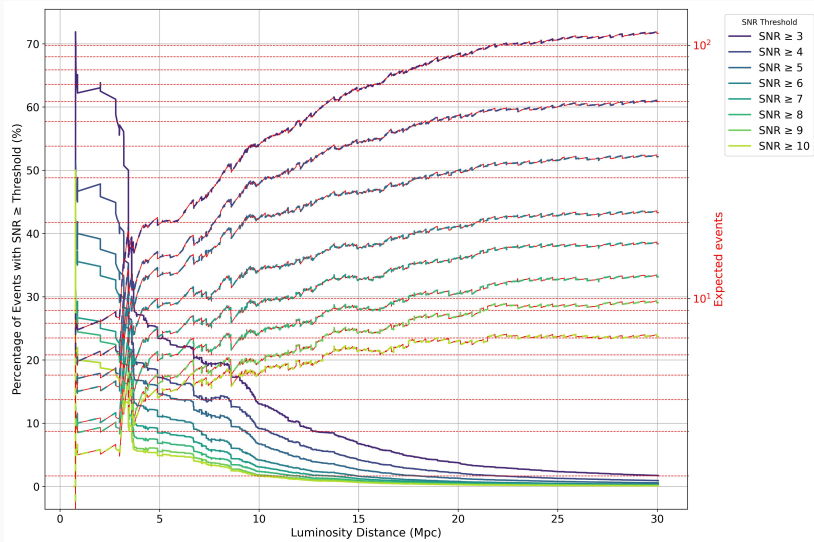
Extragalactic population: merging DWDs



Catalogue analysis: extragalactic population



Extragalactic population cumulative detection rate



accounted for incompleteness + mission duration

Conclusions

- Construction of a synthetic DWD catalogue
 - Non-trivial mass distribution
 - Critical role of merging frequency
- Detection capabilities:
 - Partial detection of MW spiralling binaries
 - High-profile study of galactic merging events
 - Good characterization of favorable extragalactic mergings within 10 Mpc
 - Observable events up to 30 Mpc
- Critical role of merging frequency
- Detection > Localization
- Special thanks to J. Harms and J.P. Zendri

Some useful articles

-  J. Harms et al., “The Lunar Gravitational-wave Antenna: mission studies and science case,” , vol. 2025, p. 108, Jan. 2025.
-  W. Li et al., “Nearby supernova rates from the Lick Observatory Supernova Search - III. The rate-size relation, and the rates as a function of galaxy Hubble type and colour,” , vol. 412, pp. 1473–1507, Apr. 2011.
-  U. Dupletsa et al., “GWFISH: A simulation software to evaluate parameter-estimation capabilities of gravitational-wave detector networks,” *Astronomy and Computing*, vol. 42, p. 100671, Jan. 2023.
-  J. V. van Heijningen et al., “The payload of the Lunar Gravitational-wave Antenna,” *Journal of Applied Physics*, vol. 133, p. 244501, June 2023.

Publications related to LGWA:

<http://lgwa.unicam.it/index.php/publications>