



Modeling the local population of DWD

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Background and motivations

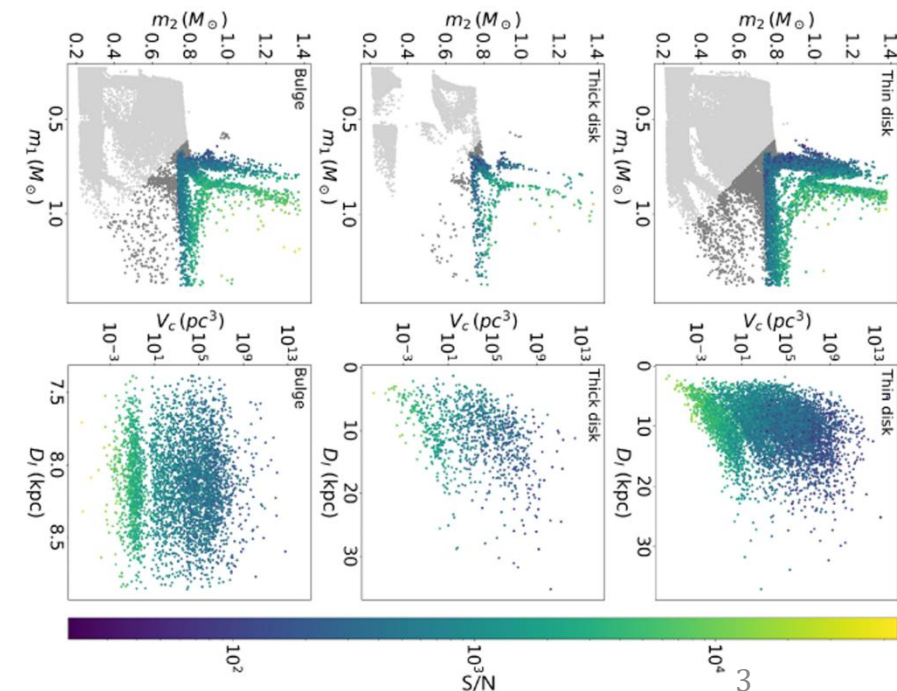
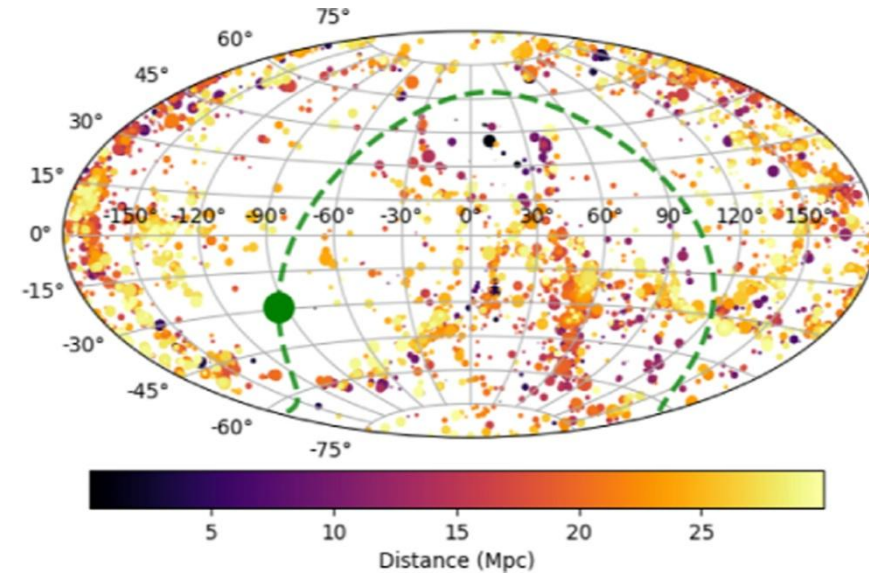
- Double white dwarfs (DWD): evolutionary endpoint of binaries ($M < 10 M_{\odot}$)
- Compact objects:
$$R(M) \approx \frac{0.022}{\mu_e} \left(\frac{M}{M_{Ch}} \right)^{-1/3} \left[1 - \left(\frac{M}{M_{Ch}} \right)^{4/3} \right]^{1/2} R_{\odot}$$
- Astrophysical importance: possible progenitors of SN Ia (DD scenario)
 - Supernova physics
 - Nuclear physics / dense matter environments
 - MM counterpart: direct Hubble law calibration / SN Ia calibration / SN formation channels
- For LGWA science case: the merging occurs in the dHz band
- How is the merging defined? What are the population properties? Can we detect and localize DWD mergers? How well?

Outline

- Population:
 - Galactic/extragalactic
 - Size
 - Characteristics
 - Uncertainties
- Observability with LGWA:
 - Merging scenarios
 - Detection
 - Sky localization and distance uncertainties

Based upon «Observing double white dwarfs with the Lunar GW Antenna»
(Benetti, Branchesi, Harms, Zendri 2026, [arXiv:2509.07849](https://arxiv.org/abs/2509.07849))

Published on A&A <https://doi.org/10.1051/0004-6361/202556940>

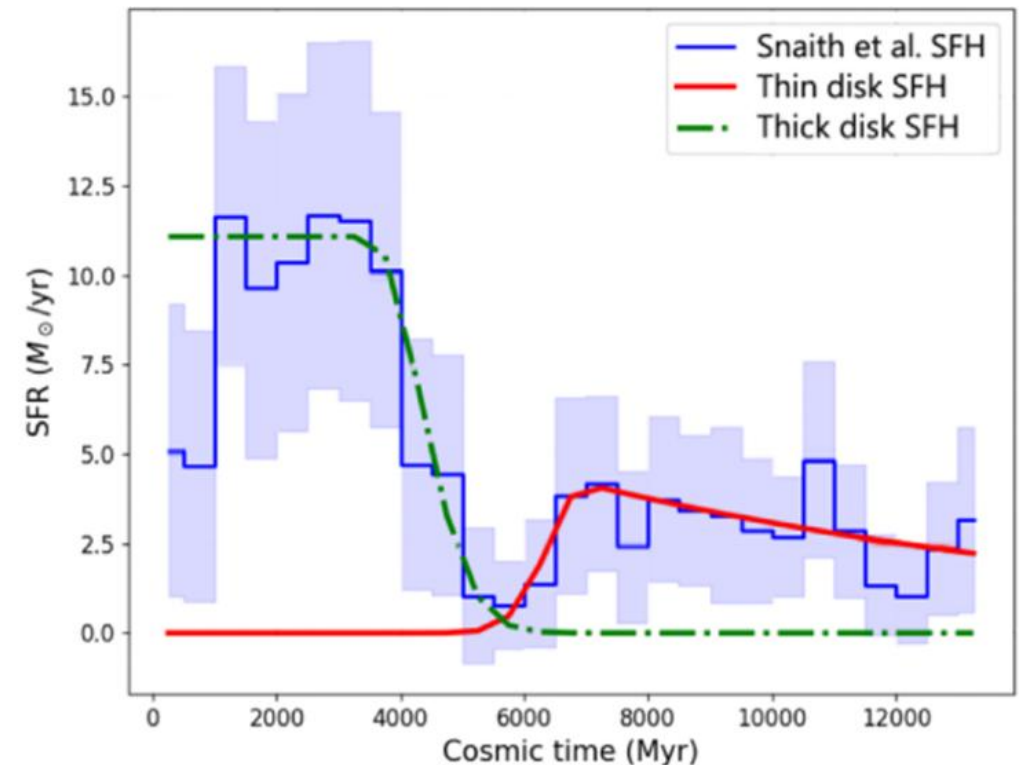


Modeling the population

- Understanding the system evolution:
 - ZAMS
 - MS evolution to WD as endpoint
 - close binaries evolution driven by GW
 - Inspiral and merger
- BUT:
 - Stellar formation modulated by a star formation history
 - Fundamentally binary evolution: common envelope episodes
 - Merger strongly determined by matter effects

Modeling the population

- Stellar evolution simulation: SeBa (Portegies Zwart & Verbunt 1996; Toonen et al. 2012)
- Formation burst convoluted with a star formation history
 - Custom SFH for different spatial components of the Galaxy (bulge + thin disk + thick disk)
 - Weak dependence induced on mass distributions
- → Current distribution of close DWDs, with coupled mass-position



Extragalactic population

- The MW population is re-weighted using the SN Ia rate to decide the global abundance, namely suppose that

*Every galaxy contains a DWD population which is
sufficient to sustain its SN Ia rate,
in the hypothesis of DD channel exclusively*

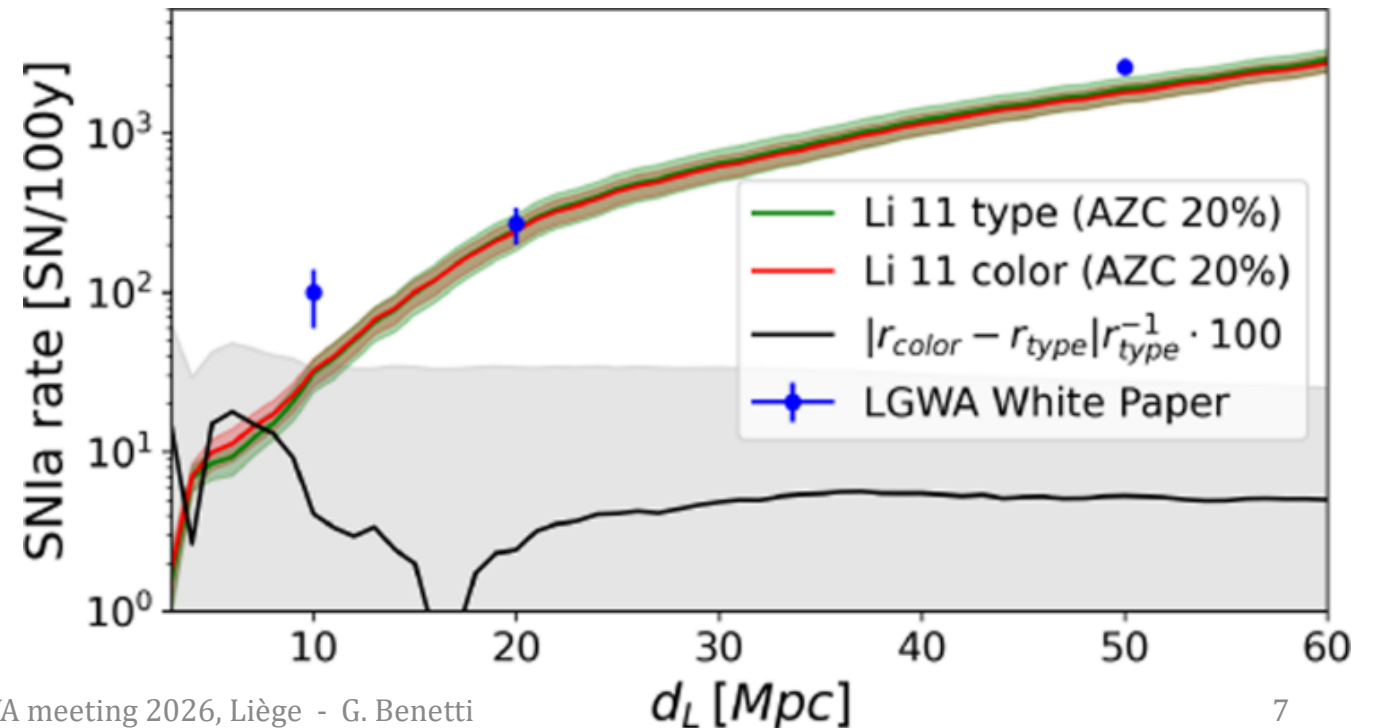
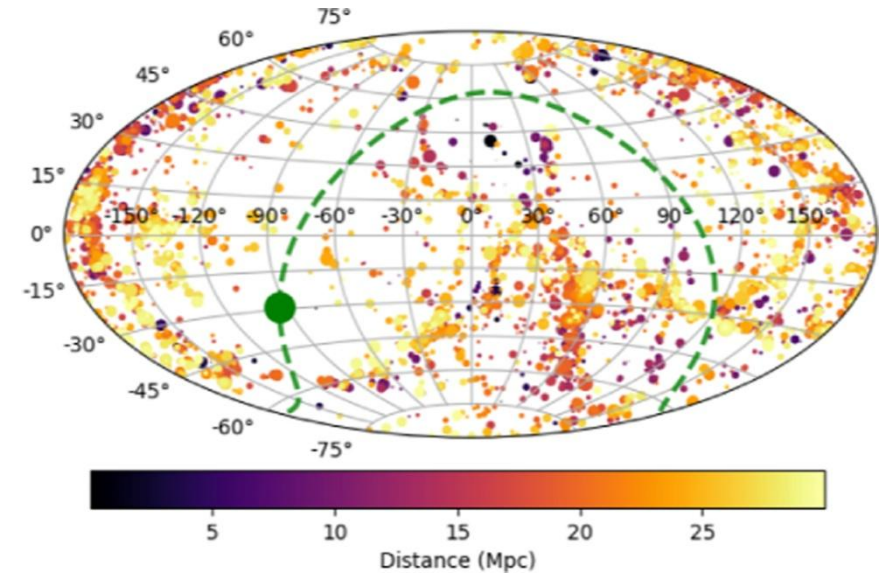
- Limitations:
 - other possible outcomes from super-Ch merging → underestimation
 - Sub-Ch SN Ia, mixed scenarios (SD present) → overestimation

Extragalactic population

- SN Ia rate: Li et al. 2011, rate-size relations

$$r(L_B) = \text{SNuB}(L_0) \cdot L_B \cdot \left(\frac{L_B}{L_{B0}} \right)^{\text{RSS}_B}$$

- Magnitudes from the HyperLEDA catalog:



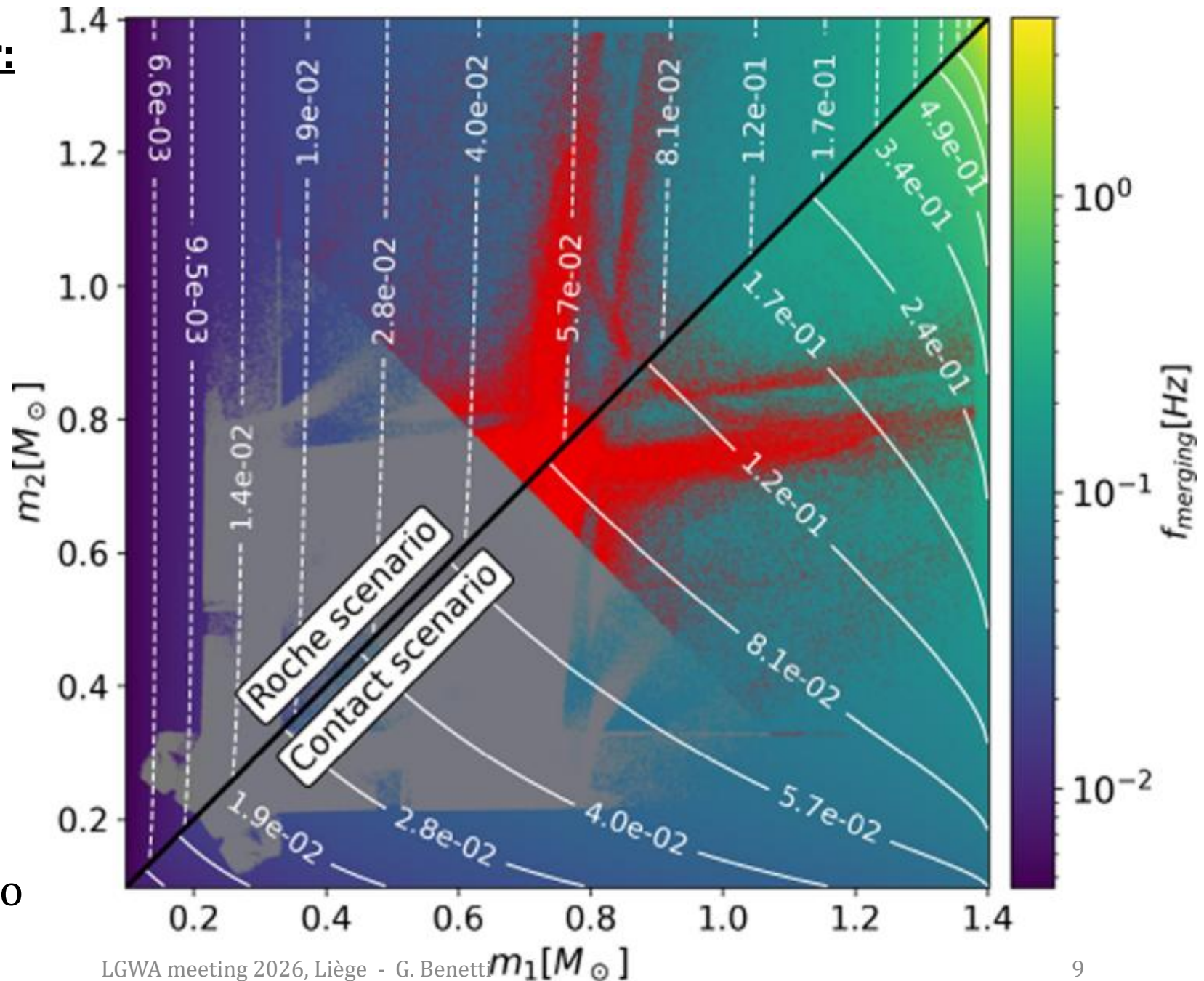
Merging scenarios

- The end of the signal is determined by the «physical» interaction between the WDs
- **Contact scenario**: the WDs behave as rigid spheres, the waveform is truncated at a frequency f such that $r_1 + r_2 = d(f)$
- **Roche scenario**: the WDs behave as fluids, the waveform is truncated at a frequency f such that $r_1 = r_{Roche}(d(f))$
- **Note**: neither of the 2 is accurate: Roche seems realistic, but the overflow does not stop the GW signal, only modifies it before actual merging
→ while contact is optimistic, could actually be a better approximation for SNR

Putting everything together:

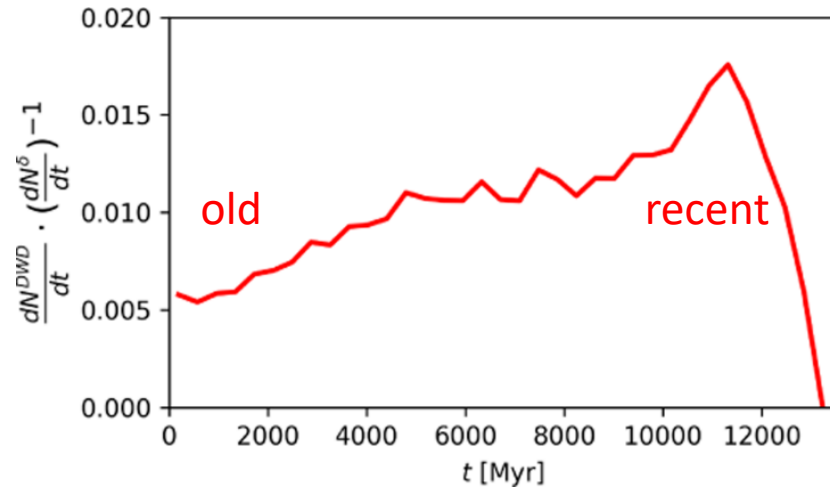
- Non-trivial mass distribution
- Different frequency dependence for different merging scenarios
- In the dHz band for super-Ch binaries (SN Ia progenitor candidates)

We now have galactic and extragalactic populations up to 40 Mpc

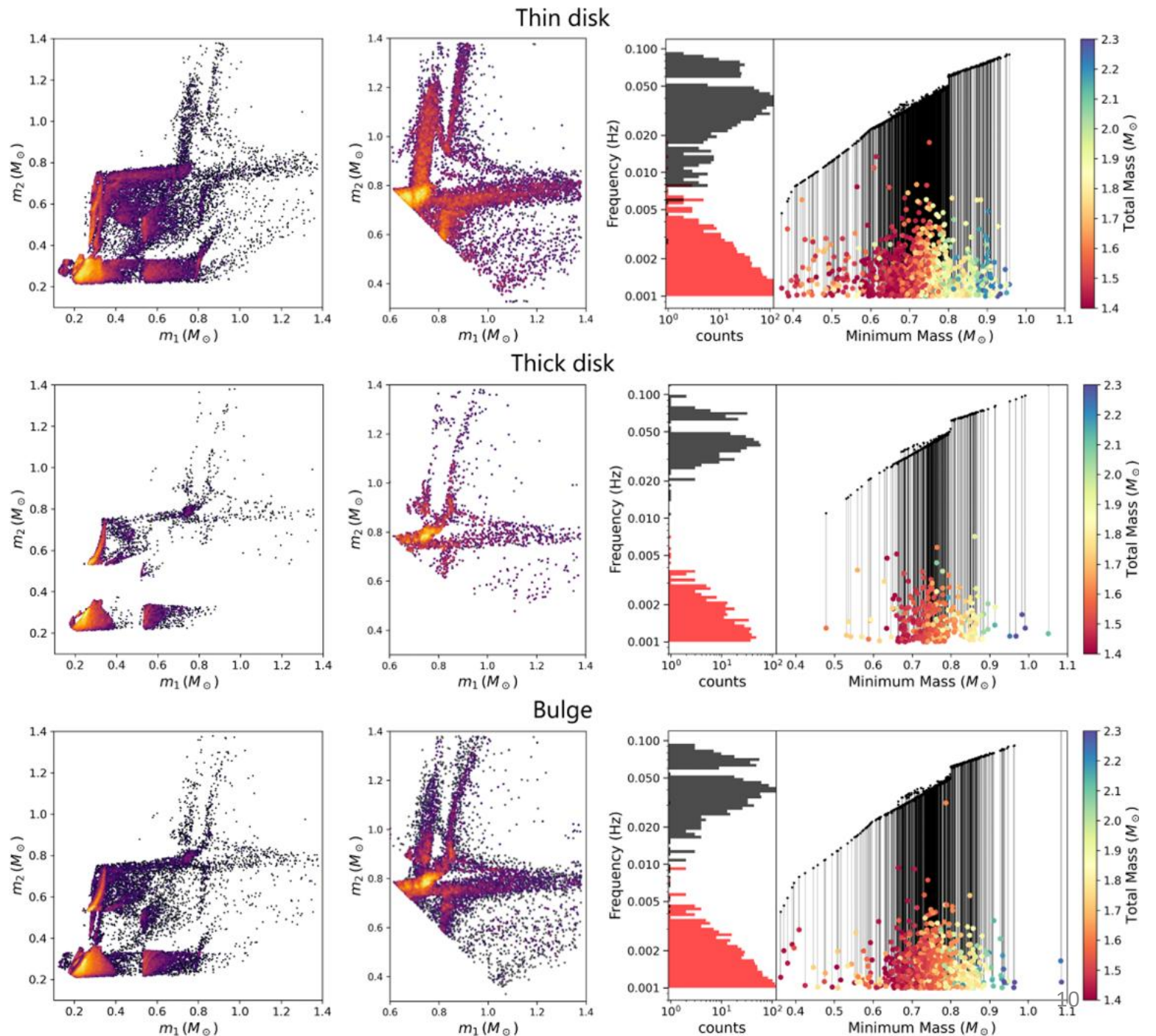


Galactic population:

- Thin disk main component, bulge depleted since too old



- Spiralling frequencies: 1mHz - 0.1dHz
- Merging (Roche) frequency: <1dHz
- Extragalactic population mirrors galactic population

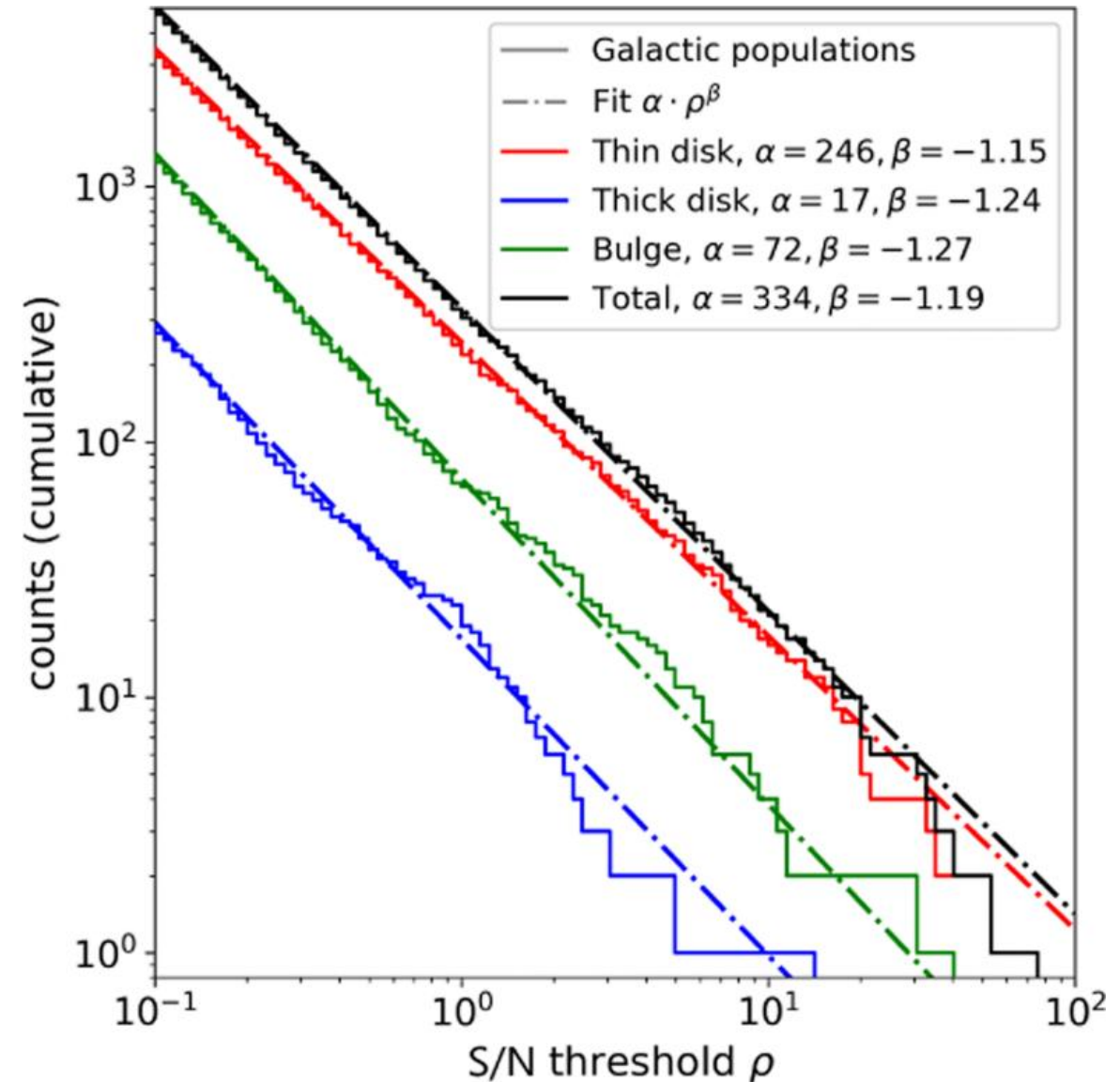


Observability

- Galactic population: basically monochromatic (no SN expected in 10 yrs)
- Treat with LEGWORK (Wagg et al 2022) : monochromatic analysis, developed for LISA
- SNR threshold = 8:
 30 ± 5 (*stat*) ± 6 (*sys*) observable

Also visible by LISA with larger SNR: not exclusive to LGWA

An opportunity for calibration?

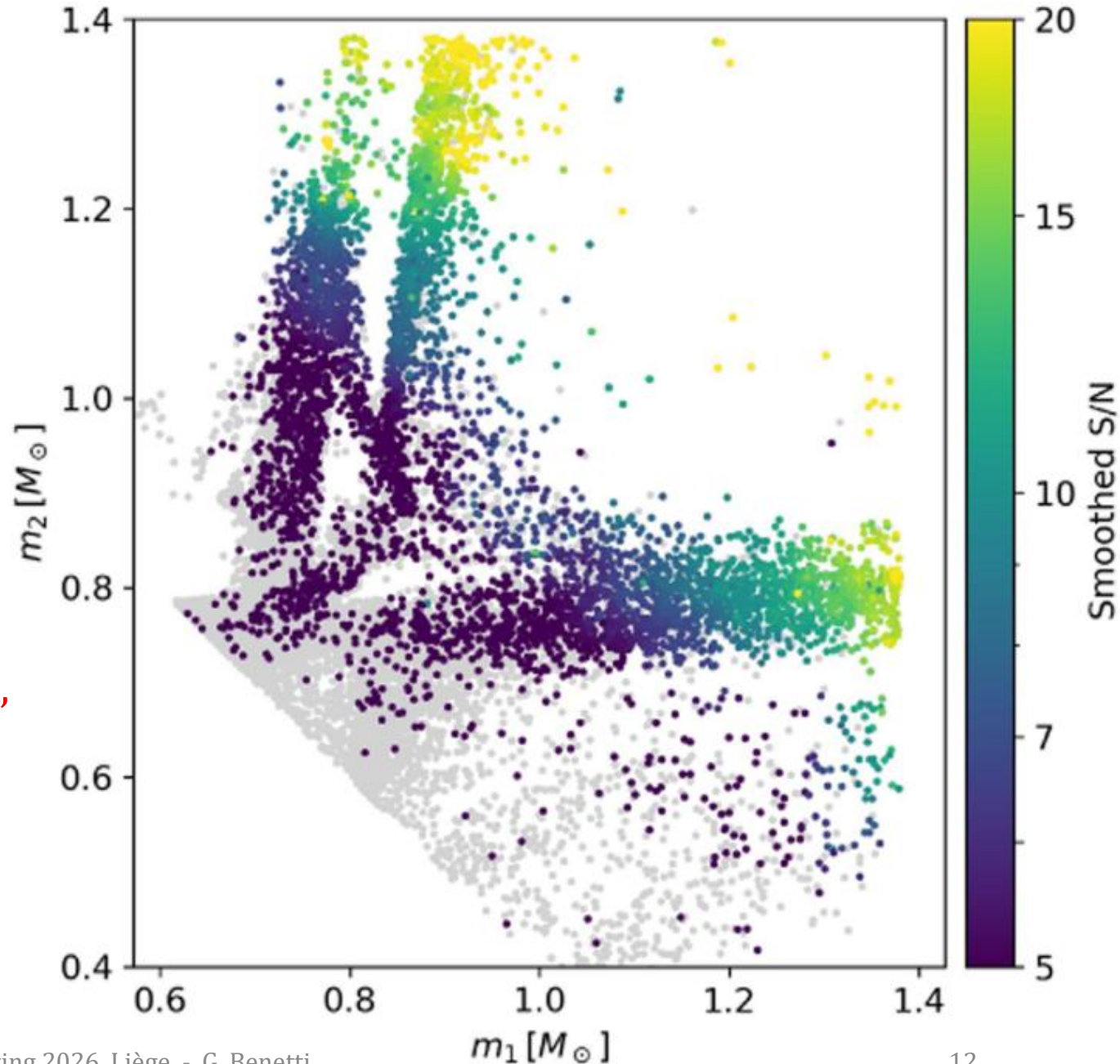


Observability

- Extragalactic population: only merging super-Ch systems
- Analyzed with GWFish (Dupletsa et al. 2023)

Without tidal and matter effects
(waveform templates!) ~ ok for SNR,
only indicative parameter estimation

- High-SNR mergings at
 $(0.8, 1.4)M_{\odot}$ (tip of super-Ch branch)

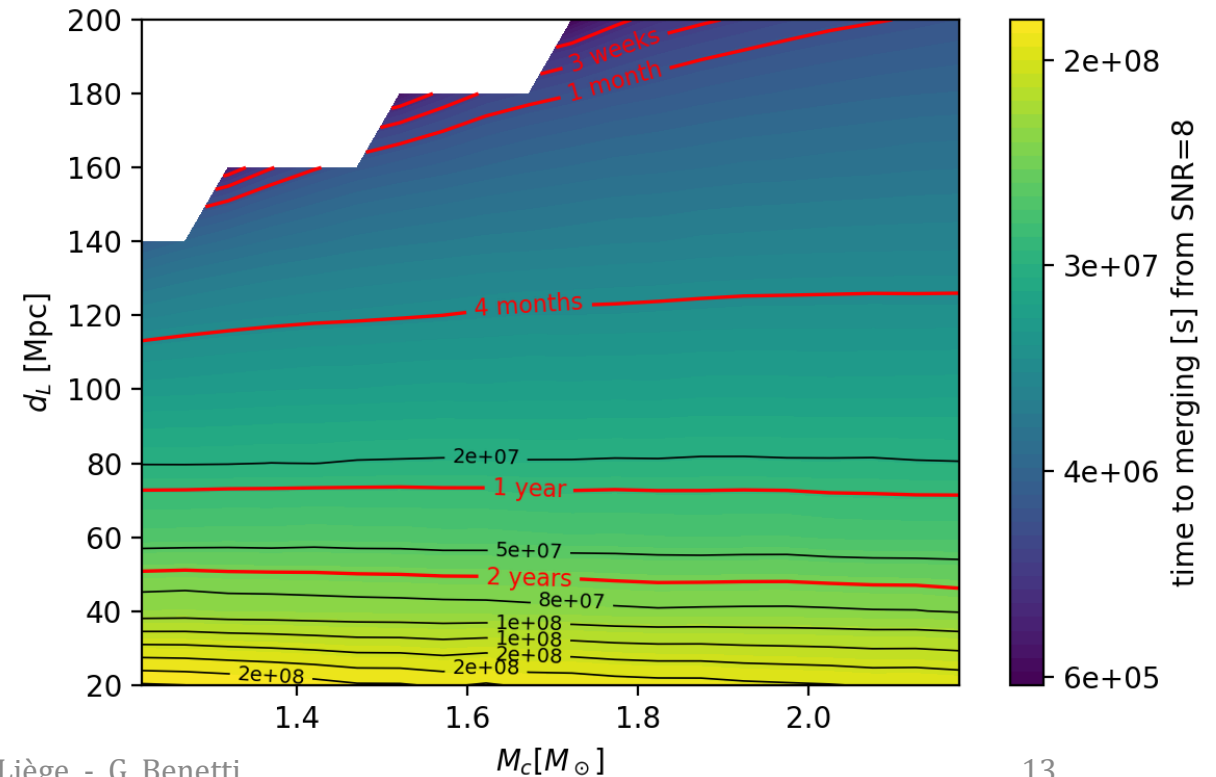


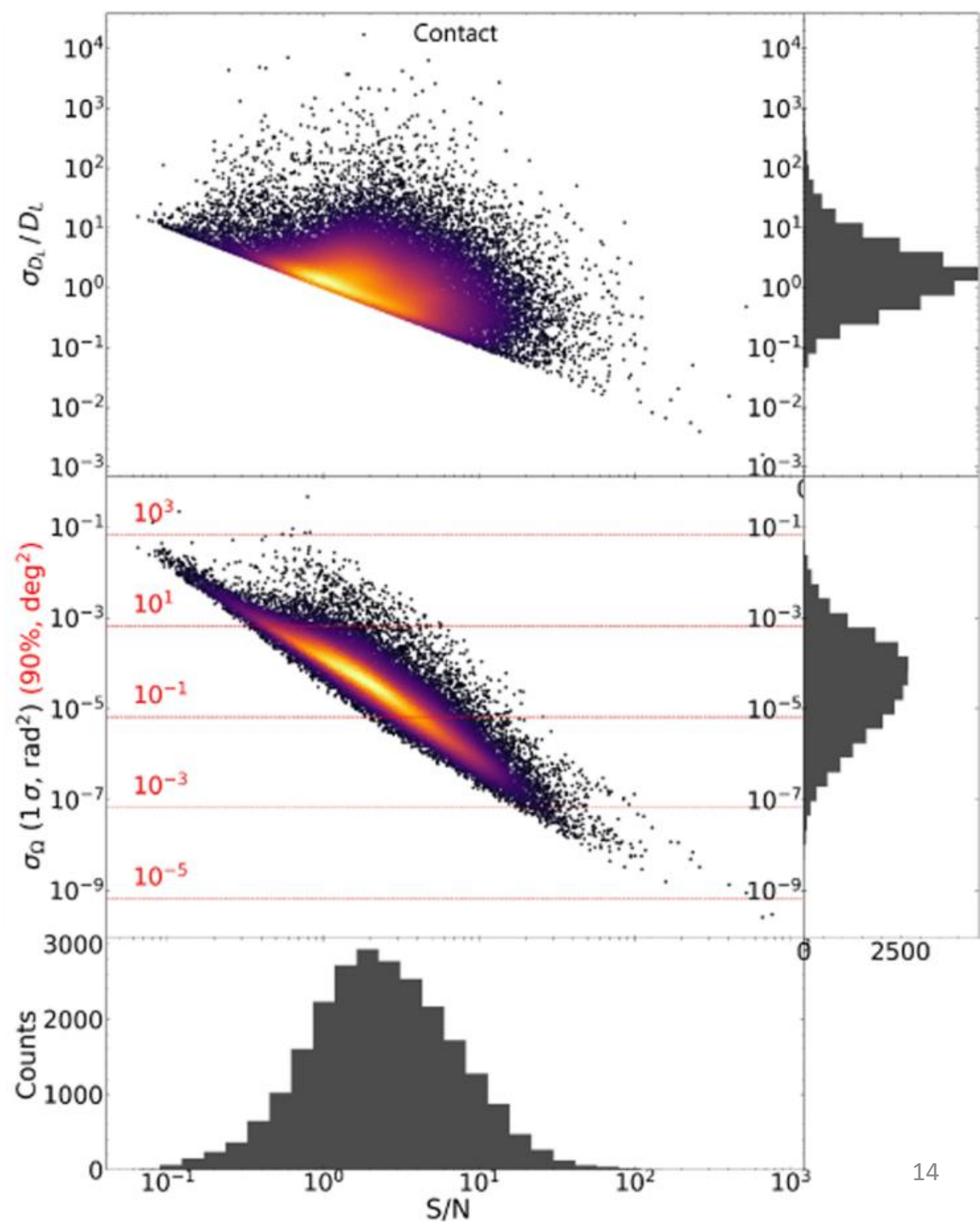
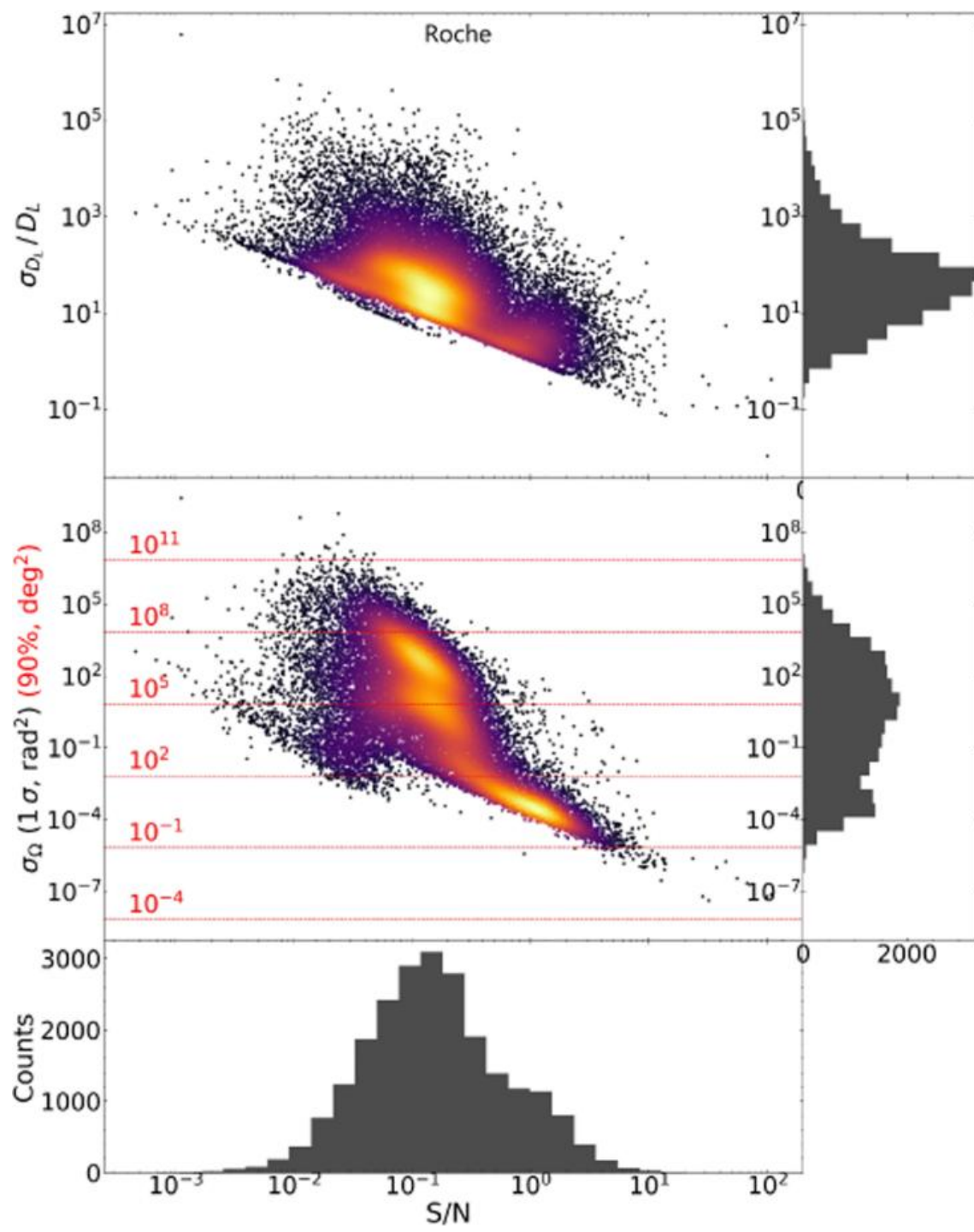
Observability

- Localization: luminosity distance + sky location
- Uncertainties define a localization volume to be compared with typical 1-galaxy volume

- DWD as standard sirens
- DWD as dark sirens
- Pre-alarm before SN Ia event (months to years) →
- Doppler peaks:

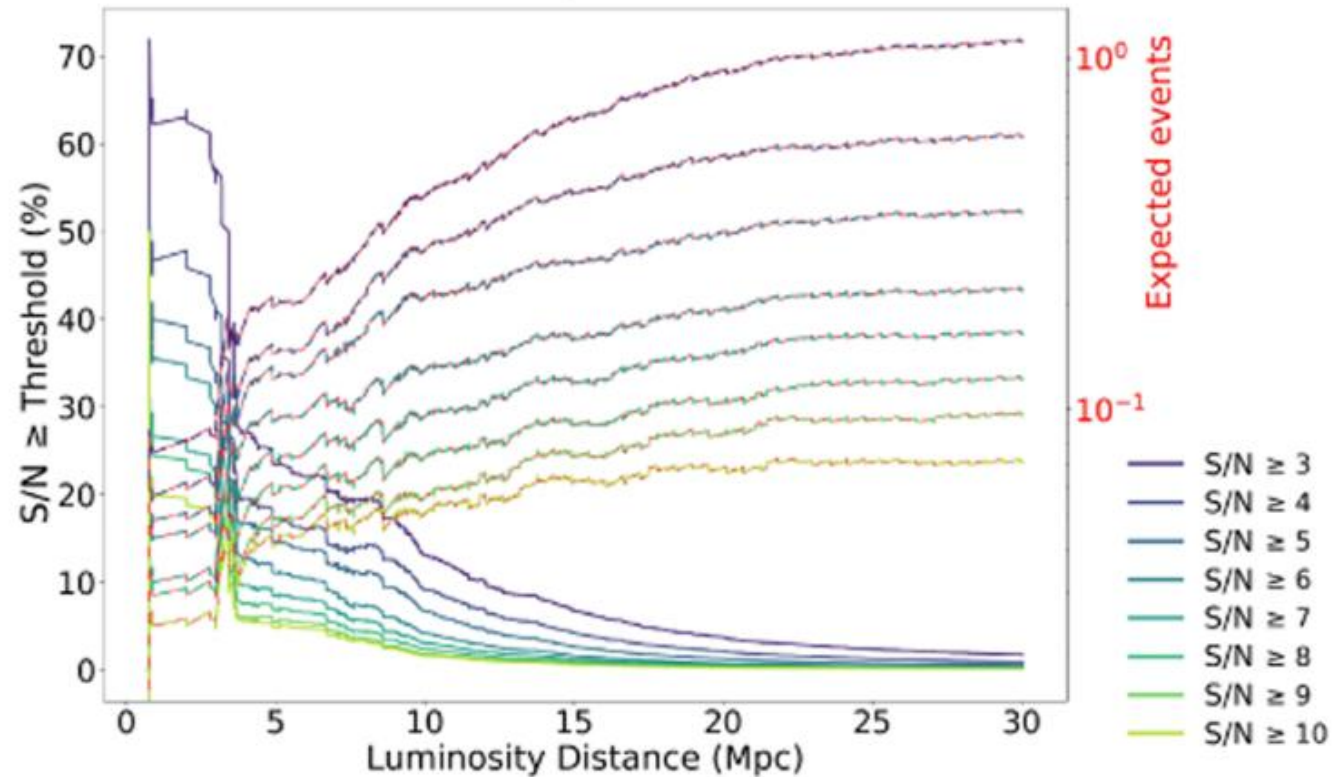
localization < detectability



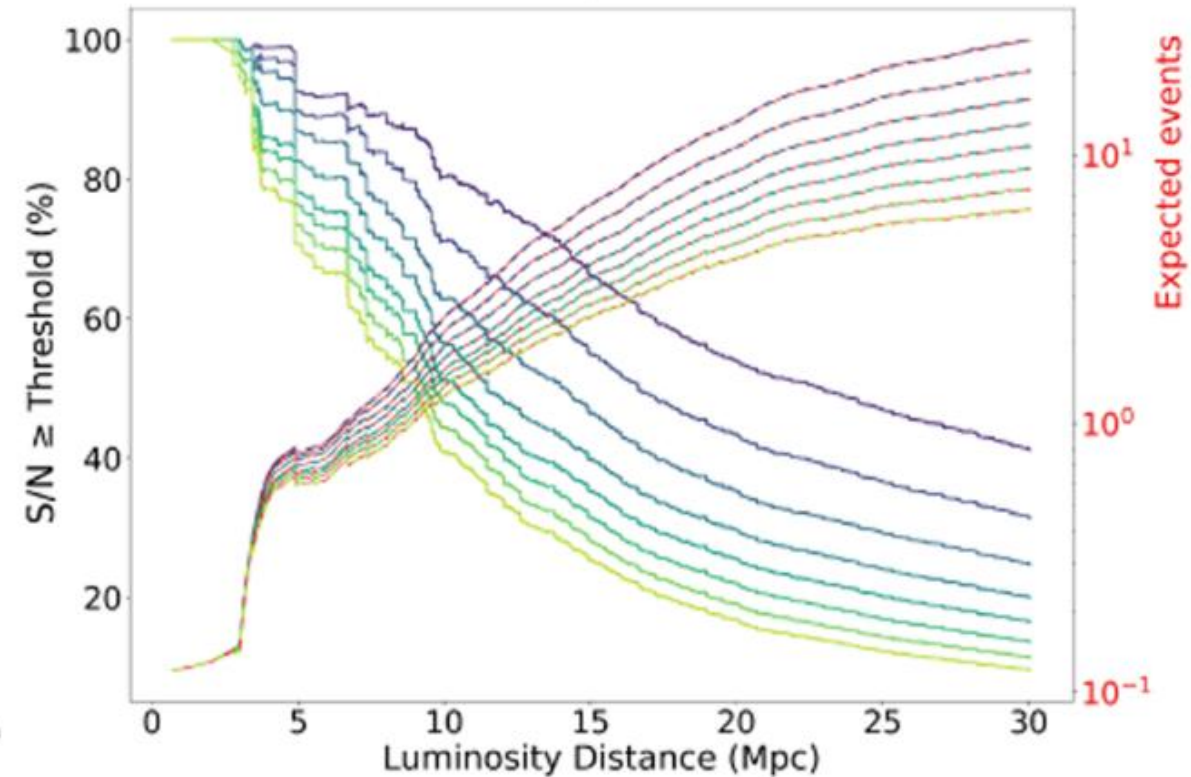


Global rates: extragalactic population

Roche



contact



Quantitative findings

		Galactic DWD (spiraling)		Extragalactic DWD (merging)	
Quantity		Value	Ref. in text	Value	Ref. in text
Detectable ($S/N > 8$)		$30 \pm 5(\text{stat}) \pm 6(\text{sys})$	Sect. 5.1	$10 \pm 3(\text{stat}) \pm 2(\text{sys})$	Sect. 5.3
Total abundance		$(5.5 \pm 0.007(\text{stat}) \pm 1(\text{sys})) \cdot 10^5$			
Super-Ch. abundance		$(2 \pm 0.01(\text{stat}) \pm 0.4(\text{sys})) \cdot 10^4$	Sect. 3.1	$50 \pm 7(\text{stat}) \pm 9(\text{sys})$	
90% sky area [deg^2]	Median	$8.6 \cdot 10^{-3}$			Sect. 5.3, Fig. 6
	95% interval				
d_L relative error	Median	$4.9 \cdot 10^{-1}$			
	95% interval				
Fiducial volume [Mpc^3]	Median	$1.5 \cdot 10^{-3}$			
	95% interval				$[2.9 \cdot 10^{-7}, 2.6 \cdot 10^{-1}]$

Sect. 5.3,
Fig. 6

Final remarks

- ✓ DWD detection is indeed possible, and relevant numbers are expected.
- △ The population has non-trivial features, such as a super-Ch branch at $m_1 \sim 0.8 - 0.9 M_{\odot}$; this should drive future targeted studies and simulations.
- △ However, it will **not** be a easy measurement, due to early Roche interaction.
- ✓ Provided detectability, unique host identification
- △ Uncertainty comes from merging phase: critical to determine even observability.
 - Waveform modeling with Roche overflow
 - MHD simulations
 - Data analysis techniques
- ✓ Uncertainties from galactic population are controlled and tested: possible variability from extragalactic (only in distribution, not abundance).