LGWA's localization capabilities on a simulated DWD population

Lunar Gravitational-Wave Antenna workshop - Oct. 2024

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9 October 2024

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Contents

- Generation of a synthetic very-short-period DWD catalogue:
  - Evolution of a generic sample primordial population
  - Convolution with a star formation history (SFH)
  - Spatial distribution
  - Absolute abundance using SNIa rates
- Analysis of the catalogue using GWFISH:
  - SNR distribution
  - Localization capabilities

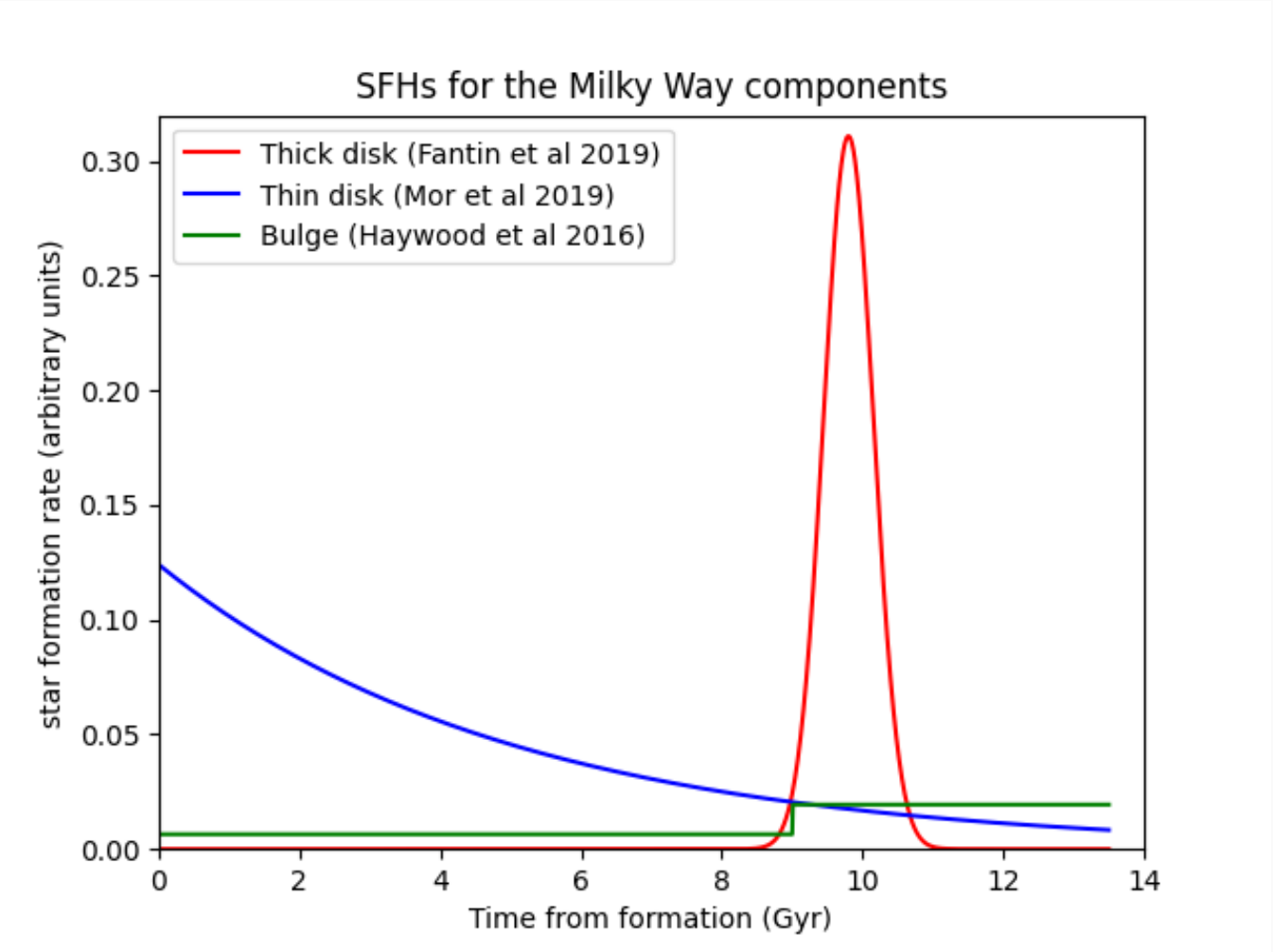
  $\Rightarrow$ scientific objectives

Motivations

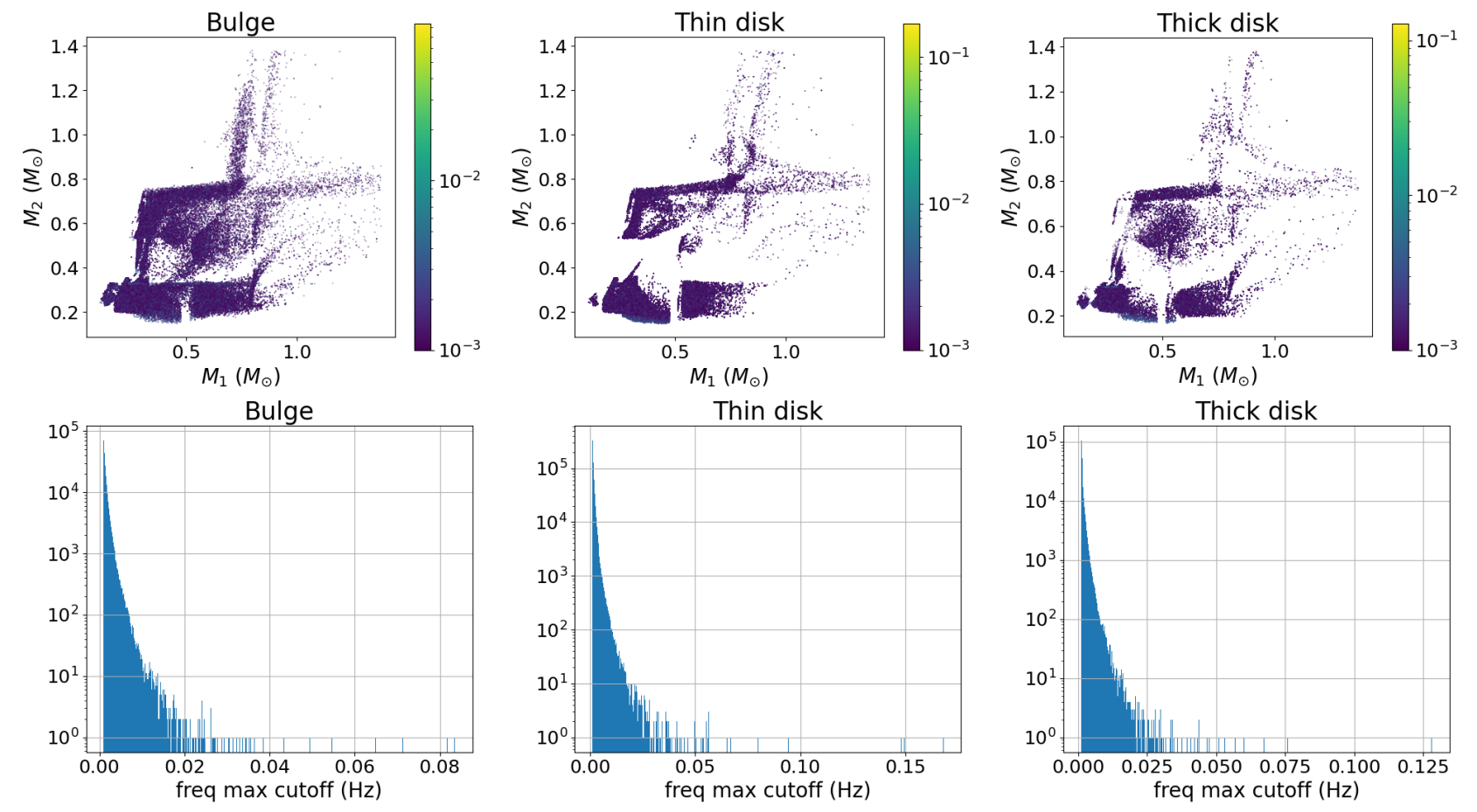
- Examine the poorly known population of very-short-period DWDs, extremely rare, but with high SNR and in the LGWA frequency band (parameters distributions, frequency cutoff due to merging, abundance, ...).
- Assess the expected contribution of LGWA to this field (large DWD population studies, physics of the merging, SNIa from DD formation channel, H_0 measurements, ...).

DWD synthetic population

- Evolution of a primordial population of $2 \cdot 10^6$ binary systems for 13.5 Gyr (construction of a δ burst with known history). Evolution performed by SeBa (Portegies, Zwart & Verbunt 1996; Toonen et al. 2012).
- Convolution of the burst with a chosen SFH:

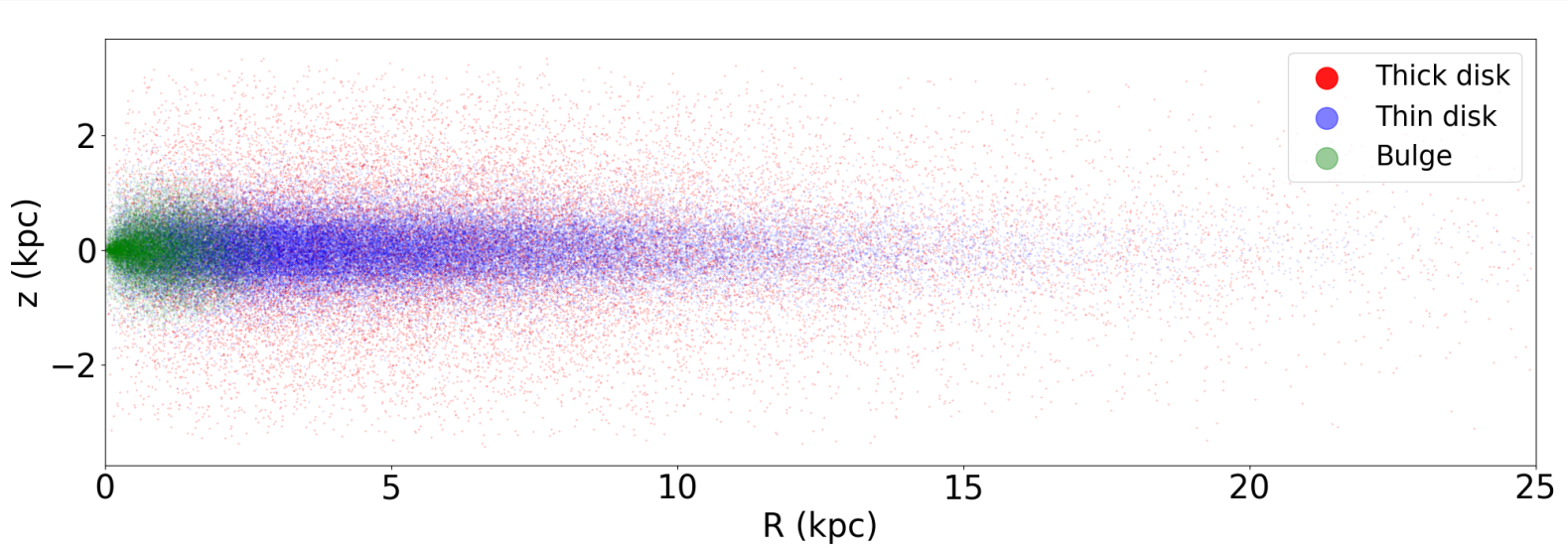


DWD synthetic population



DWD synthetic population

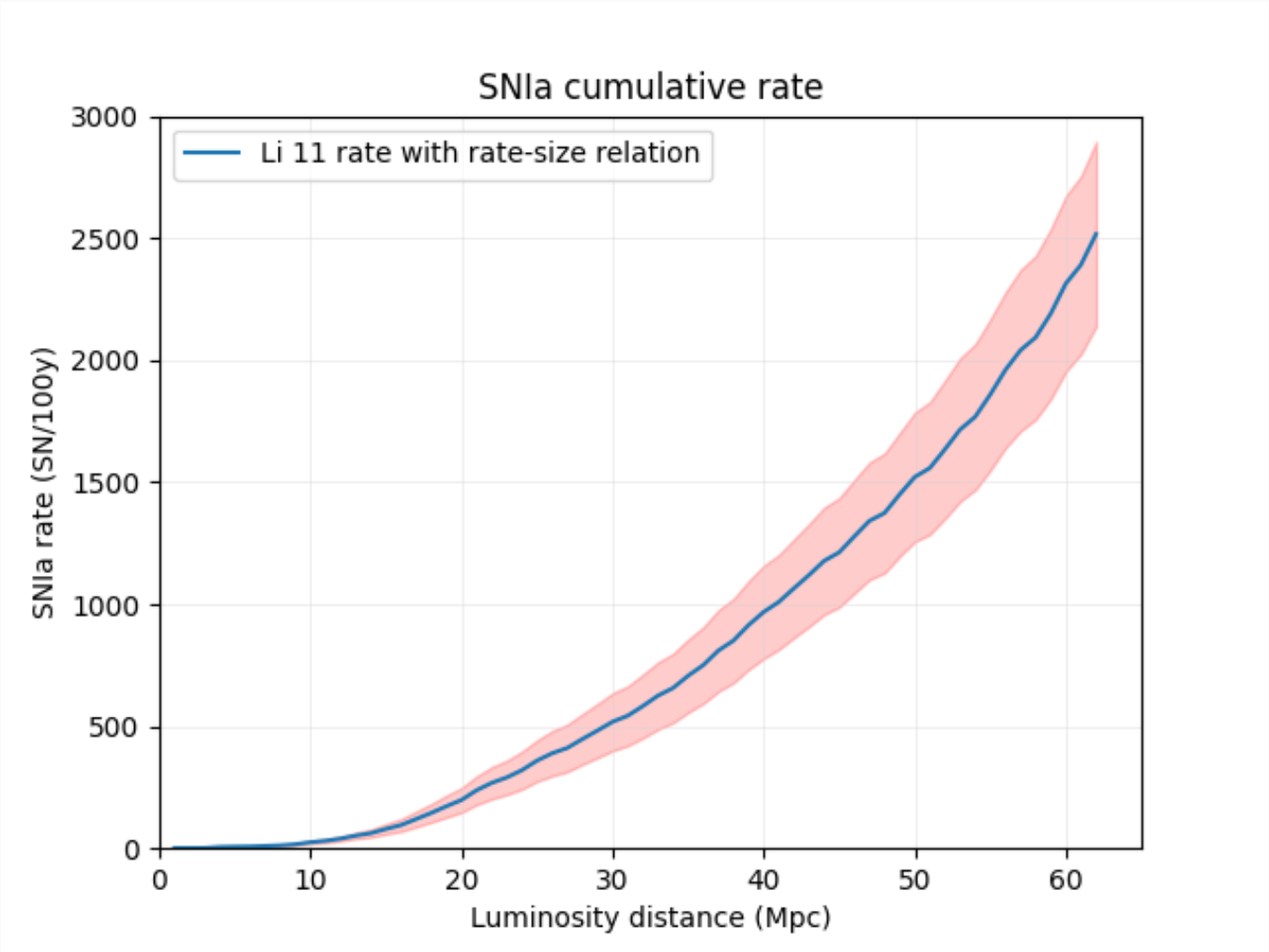
- Spatial distribution within the MW following the known stellar densities for the components



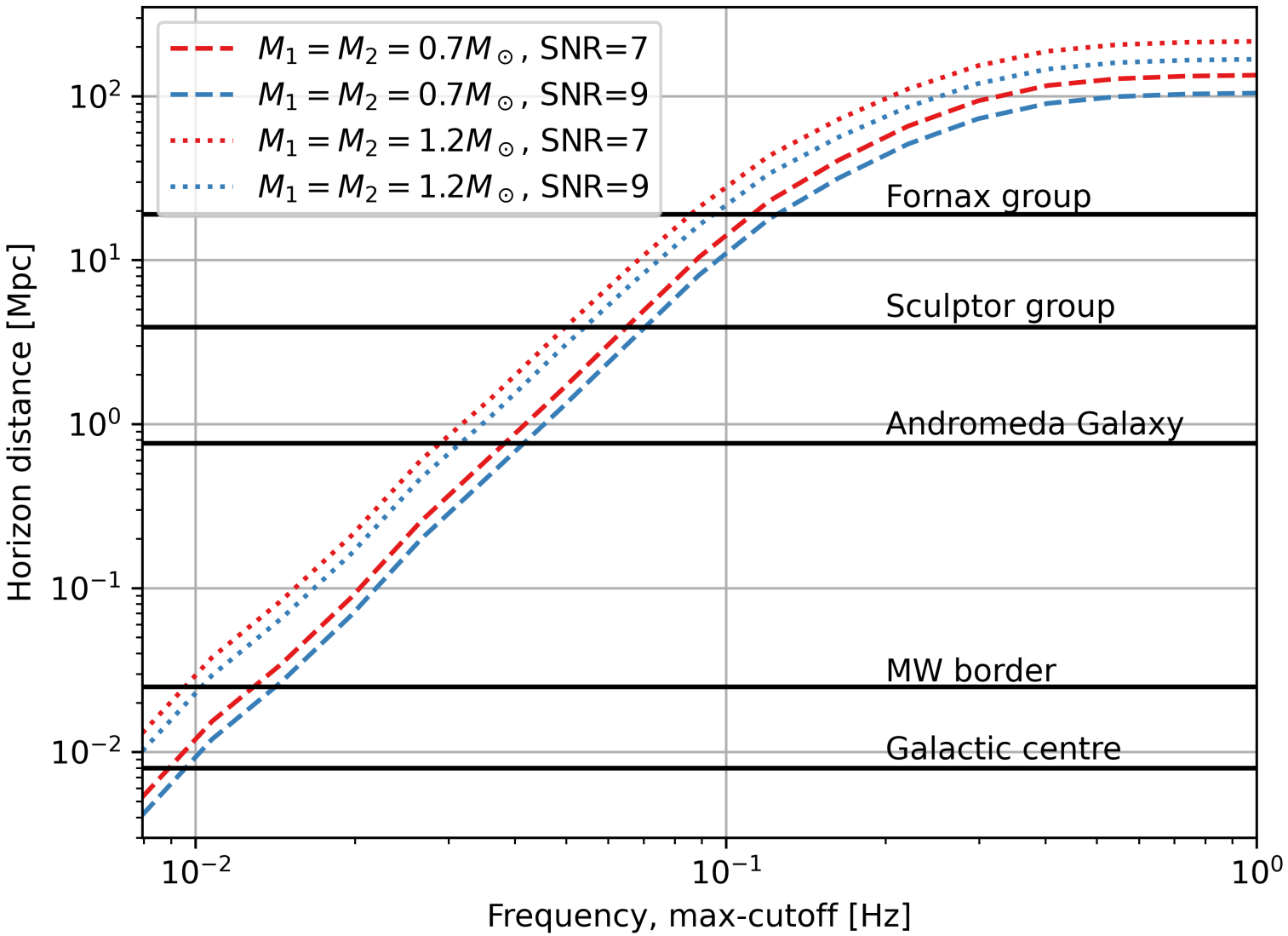
- Total abundance chosen to match the SNIa rate, in the hypothesis of exclusively DD channel.
  $r = (5.4 \pm 1.2) \cdot 10^{-3}$ SN yr^{-1}, see white paper.

DWD synthetic population

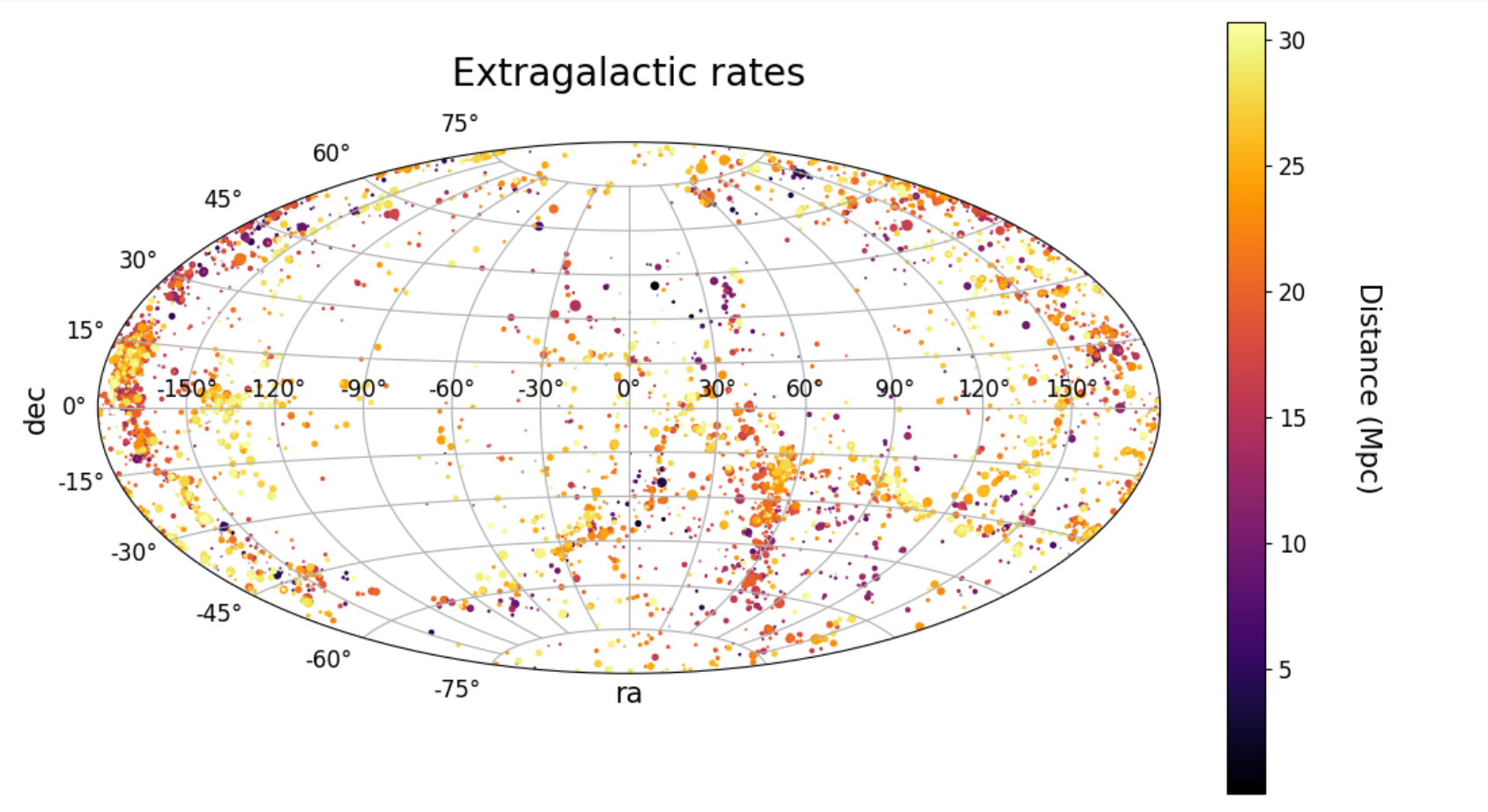
Extragalactic population: rates from Li et al. (2011), rate-size relation (considering B magnitude and morphological type or B-K colour) applied to the HyperLeda catalogue



DWD synthetic population



DWD synthetic population

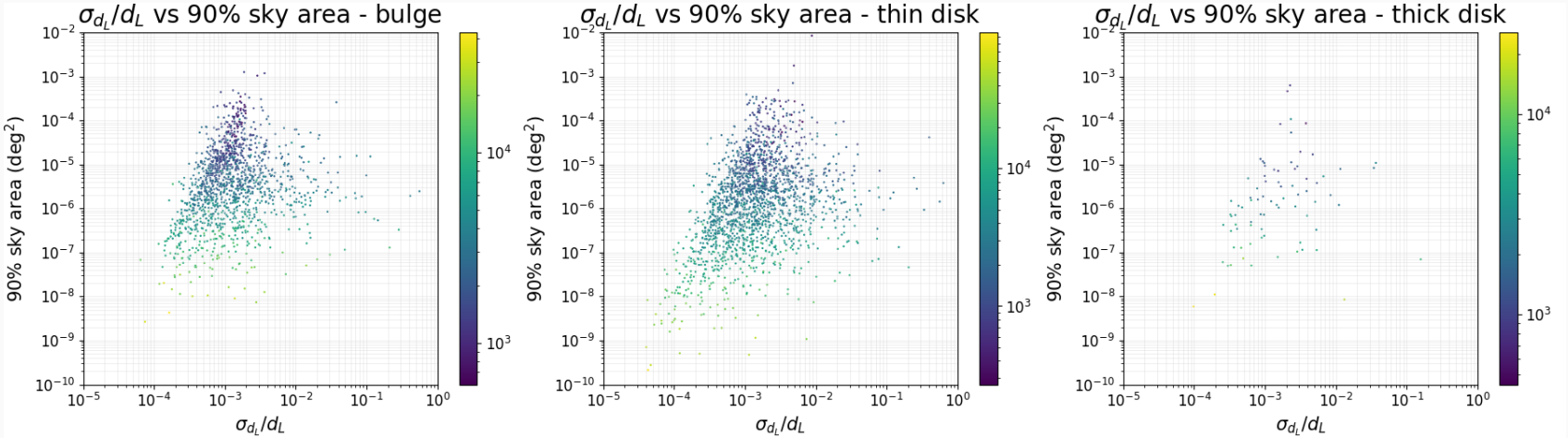


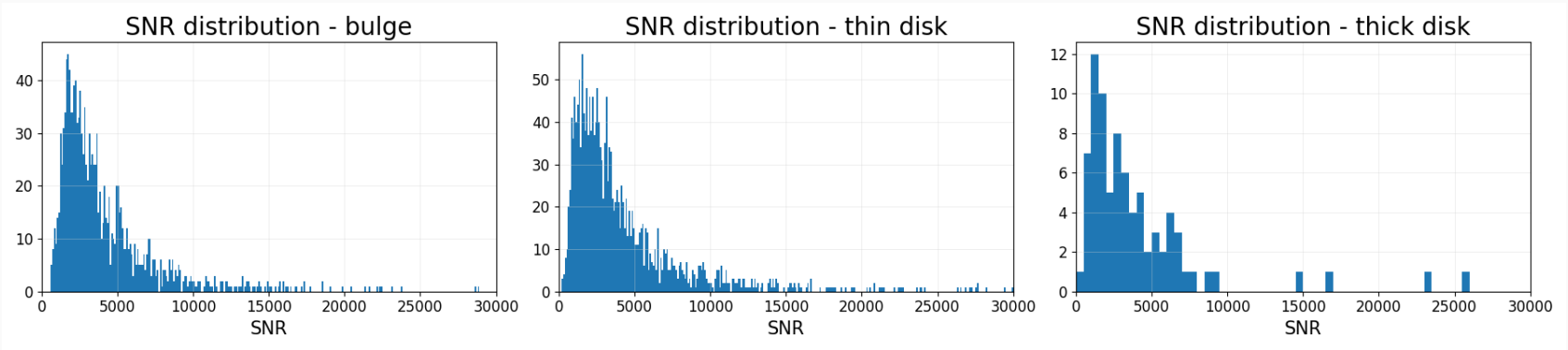
⚠ HyperLeda incompleteness not accounted (≈ 20%)

Catalogue analysis

- Analysis performed with GWFISH (Dupletsa et al. 2023)
- Due to current software limitations, only the **super-Chandrasekhar merging** population is analyzed $\Rightarrow$ **statistical study over** 10^5 **years**
- Detectability: SNR of the events
- Localization: error on luminosity distance and sky localization
  - "Confusion limit": maximum tolerable volume to recognize the source as the optical counterpart, given by the local density of stars/galaxies.

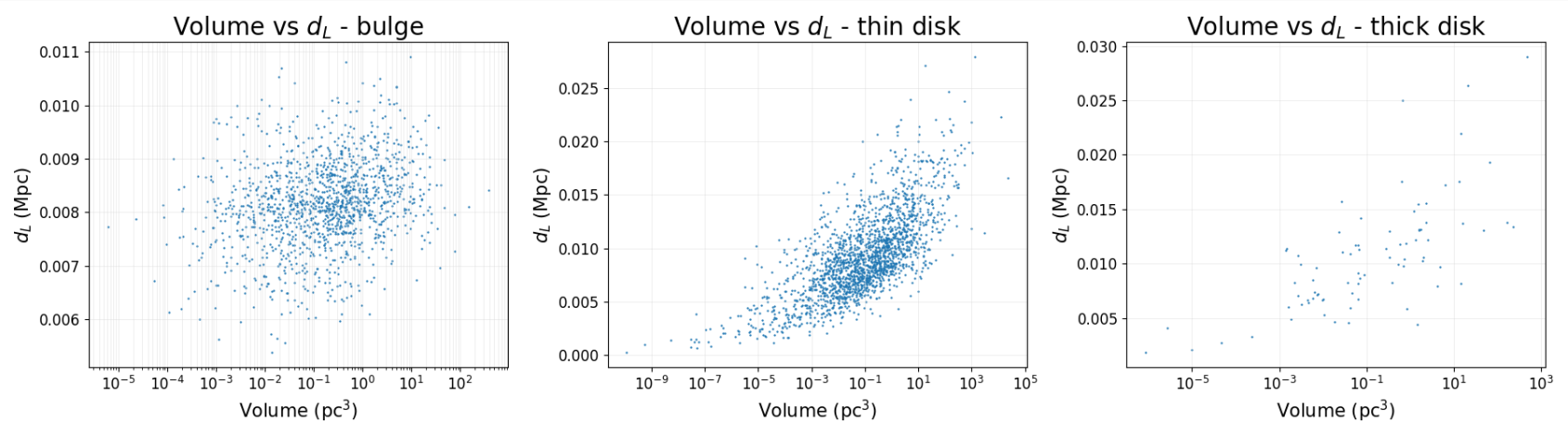
Catalogue analysis: galactic population





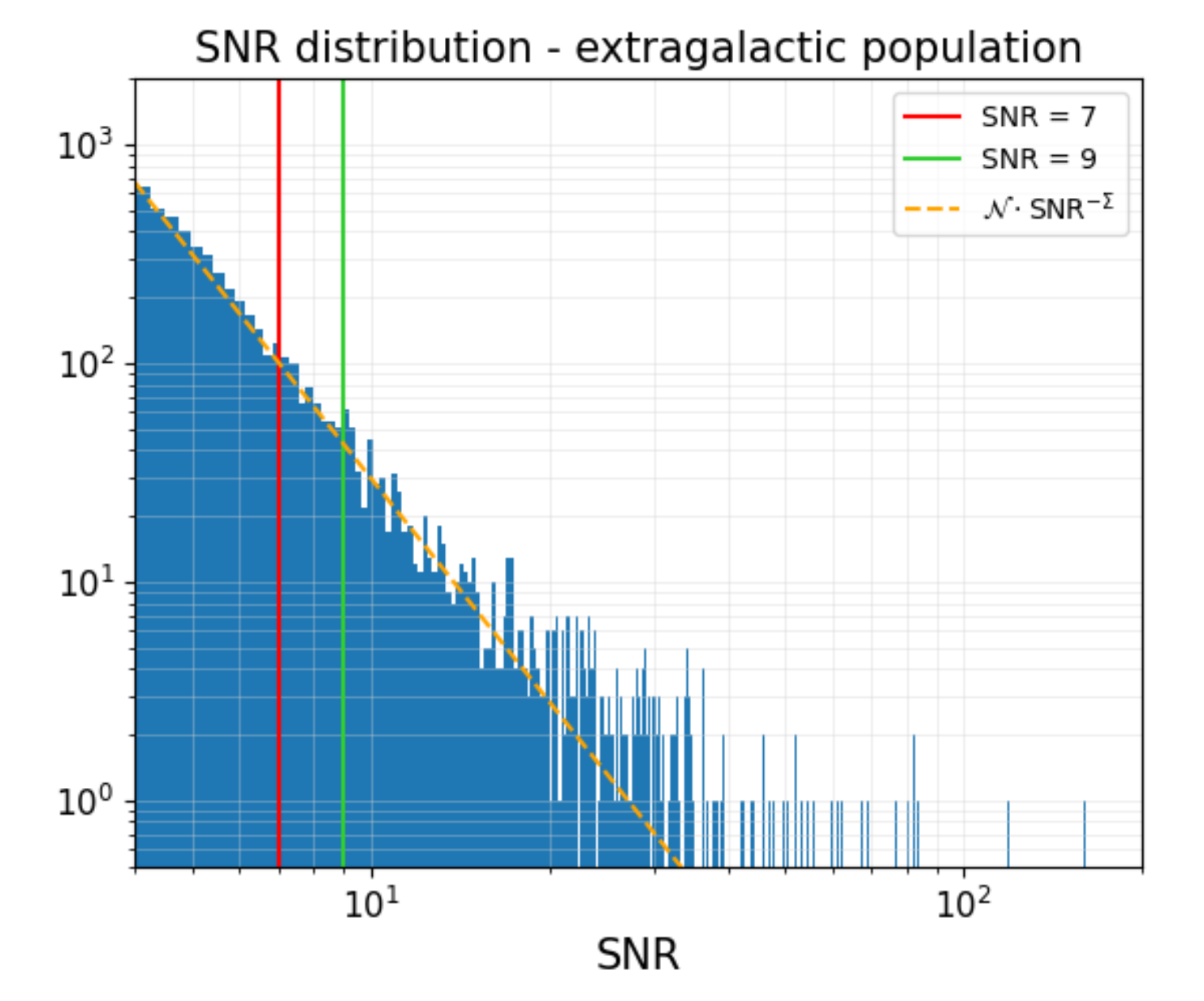
Catalogue analysis: galactic population

Approximate volumes given by 1σ errors:

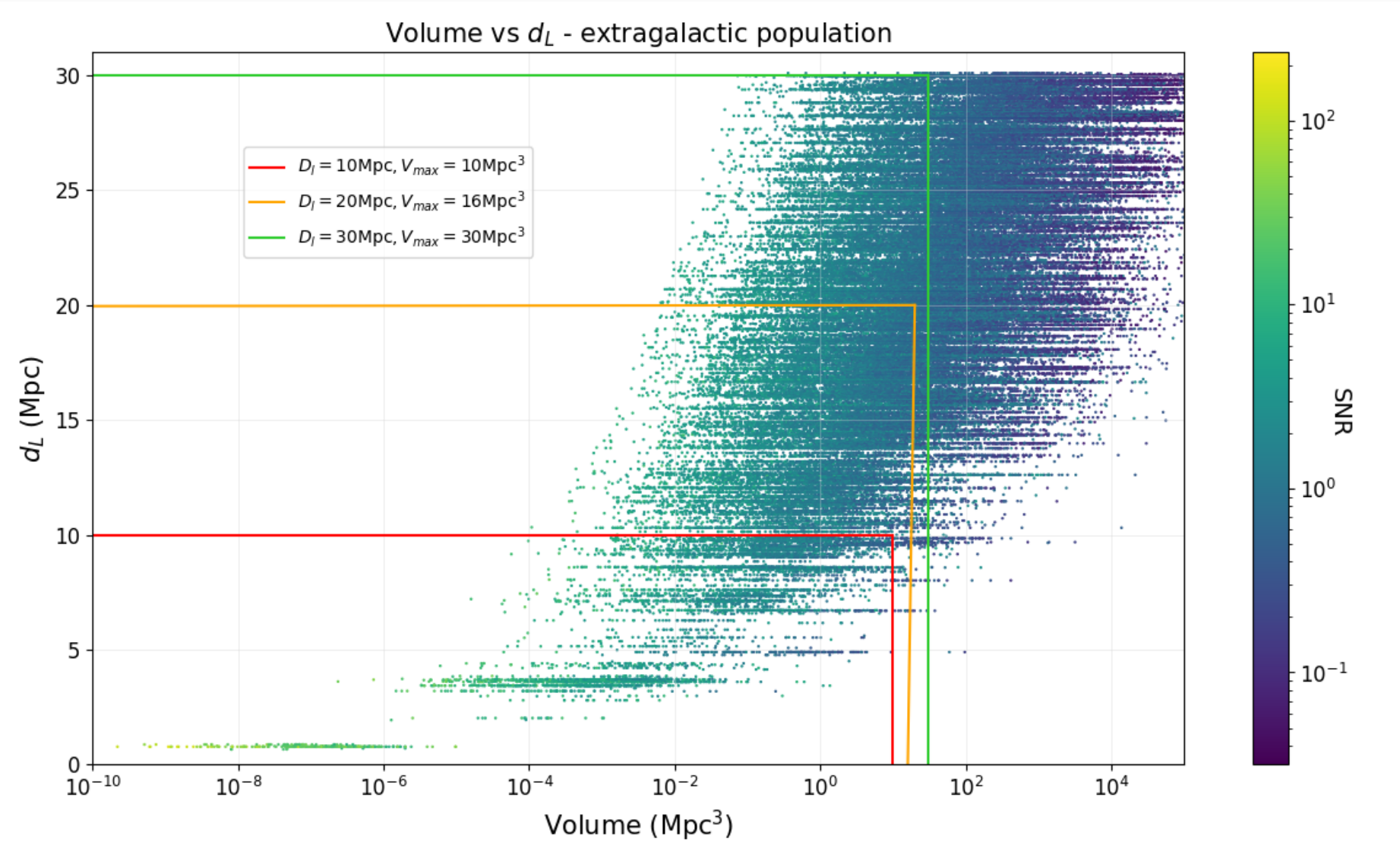


All volumes below a reasonable confusion limit.

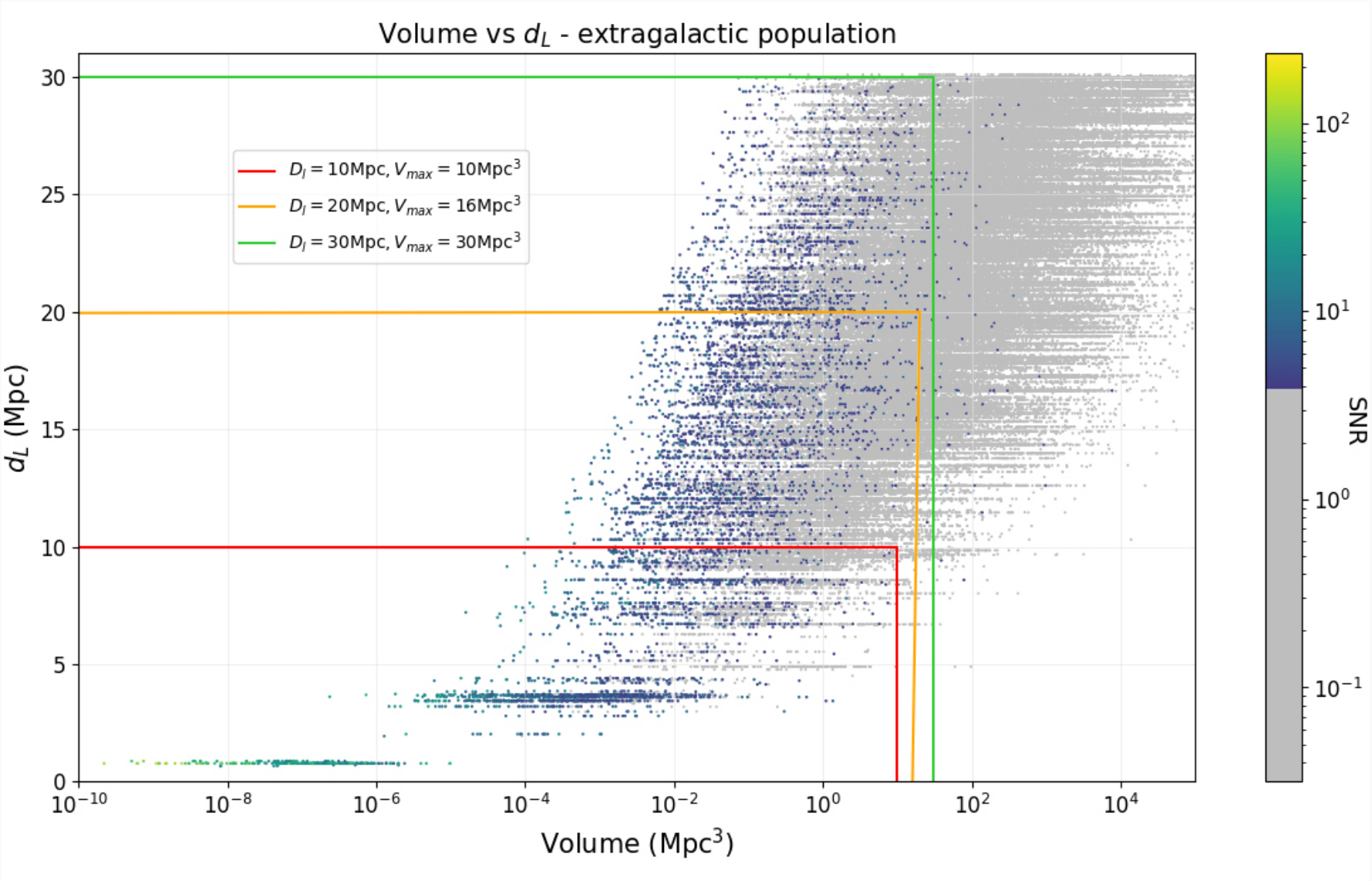
Catalogue analysis: extragalactic population



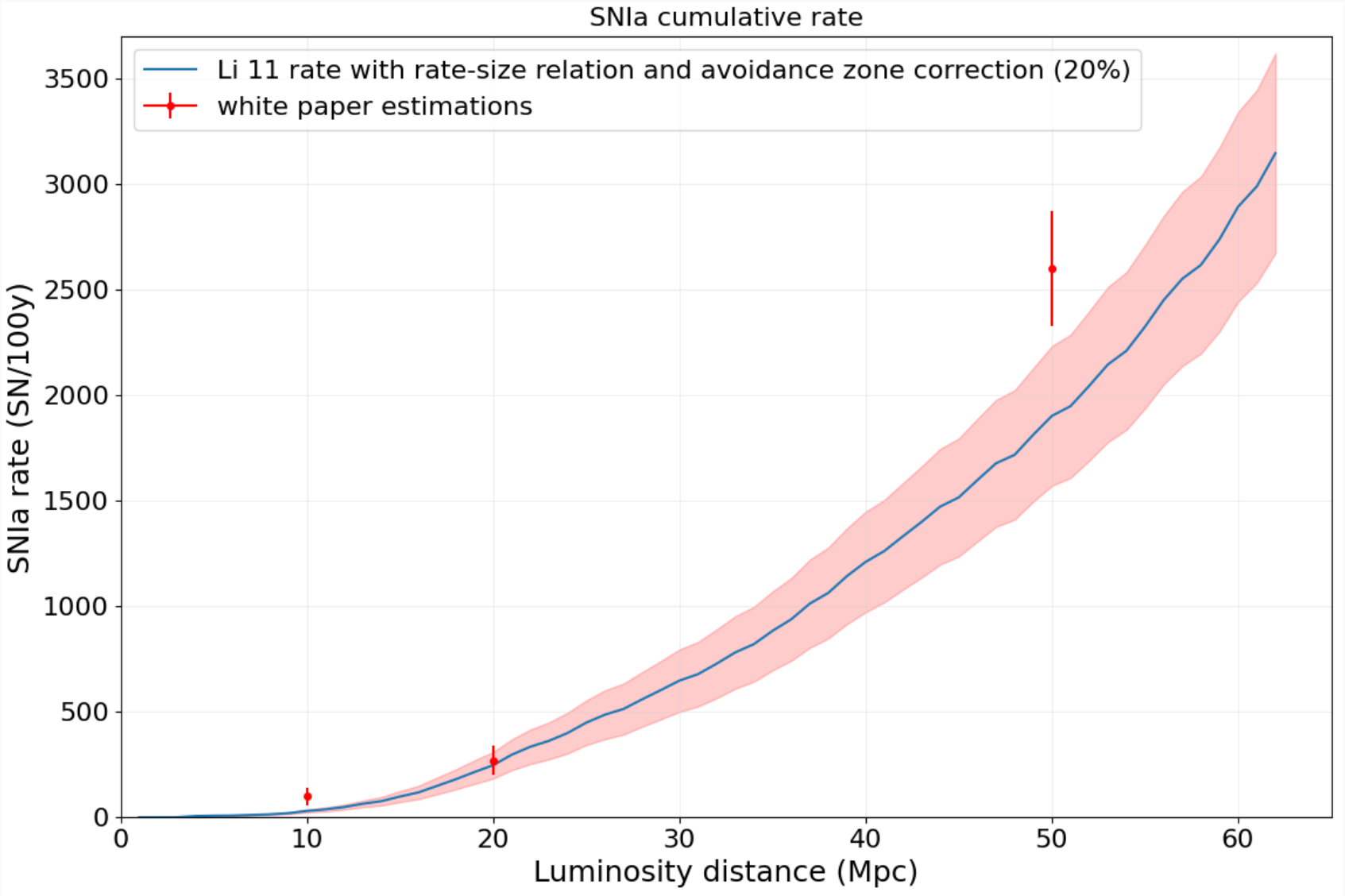
Catalogue analysis: extragalactic population



Catalogue analysis: extragalactic population



Catalogue analysis: extragalactic population



Future work

- Computational issues:
  - Analysis of stationary sources (spiralling DWDs): vast majority of observable sources inside the MW.
  - Analysis of sub-Chandrasekhar binaries: consistent population that could be observable.
- Theoretical issues:
  - Improving the automatic calculation of the frequency cutoff due to tidal disruption: very critical parameter in the calculation of SNR and localization.
  - Improving star evolution simulations (metallicity)
- Further step: same analysis at different mission durations.

Conclusions

- Construction of a synthetic DWD catalogue.
- Detection capabilities:
  - High-profile study of galactic events
  - Complete population studies within 5 Mpc
  - Good characterization within 10 Mpc
  - Observable events up to 30 Mpc and further
- Detection > Localization

Acknowledgements

Thanks to my thesis supervisors,

prof. **Jan Harms** and prof. **Jean-Pierre Zendri**

Thank you for the attention