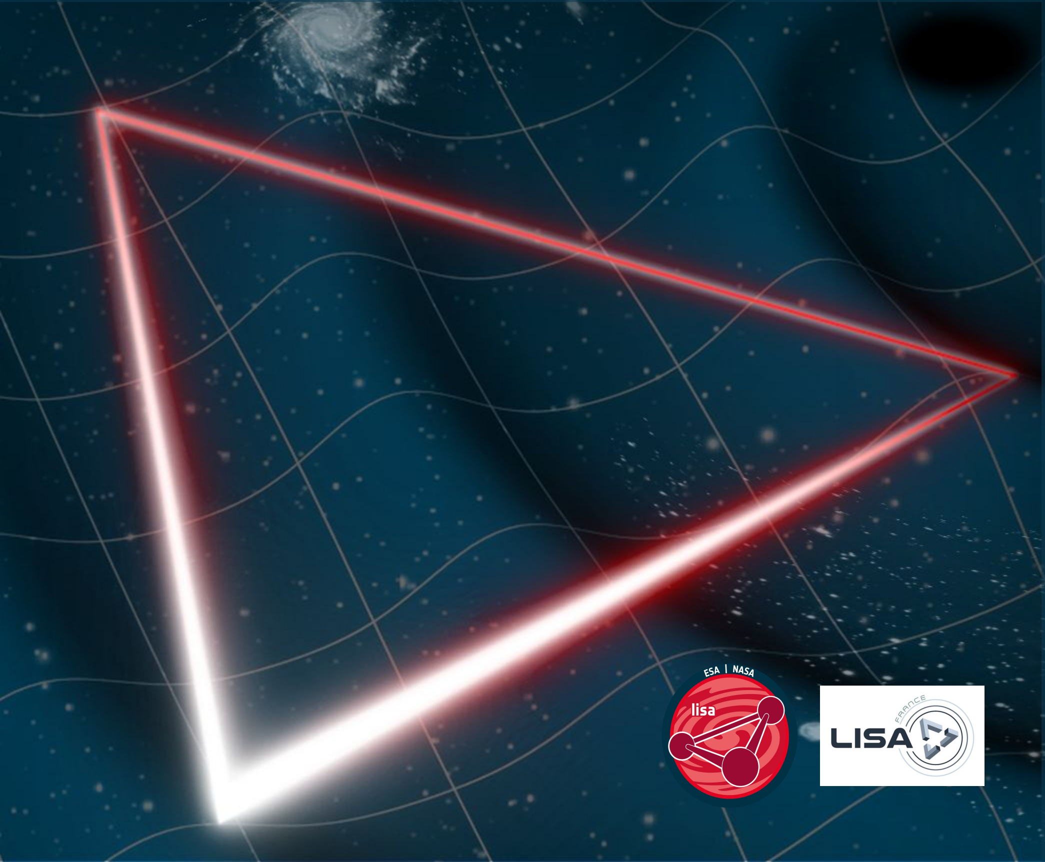
Journées LISA France, Paris
May 5th 2026



Towards systematic searches for LISA DWDs with multiband photometry

Alice Perego, Observatoire de la Côte d'Azur

Astrid Lamberts, Mathias Schultheis, Nelson Christensen

— LISA double white dwarfs (DWDs)

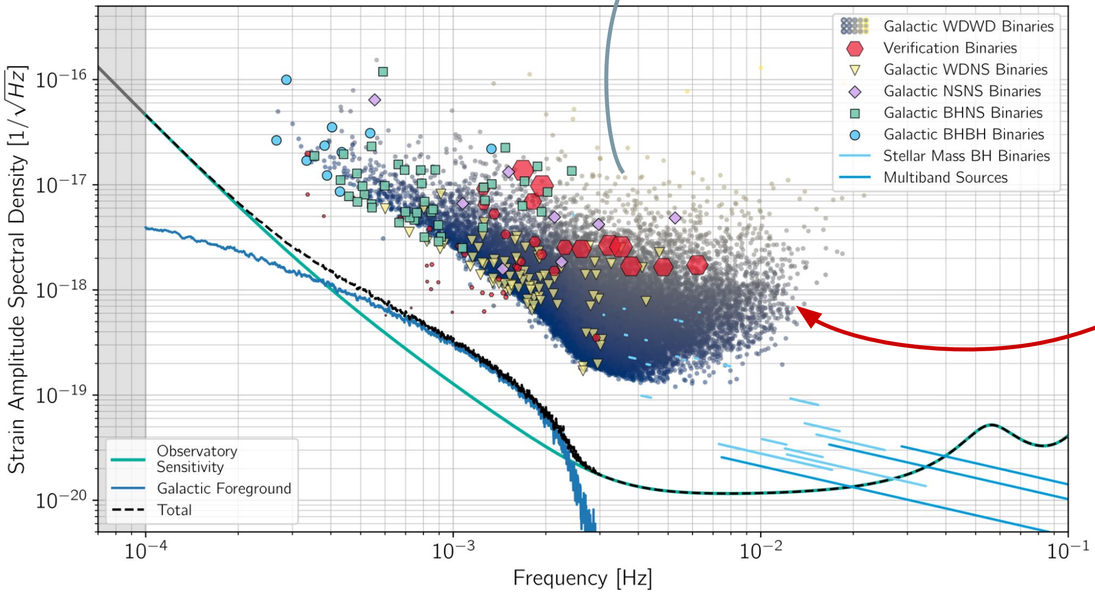
LISA science case: ultra-compact DWDs

- ~10'000 individually detected
- foreground signal in the detector

Optical EM emission of white dwarfs

Valuable multimessenger sources
(Verification binaries …)

LISA Red Book



— Multimessenger astronomy for LISA

→ **Goal :** extend the EM catalogue of **LISA double white dwarfs** (DWDs) with systematic surveys

WHY ?

- LISA **performance** and **data analysis**
  well-known EM binaries → instrument calibration, decrease of global noise budget
  current sample of ~30 *verification binaries* (detached DWDs)

- Combining GW and EM measurements
  - constraints on GW parameters, improving their **accuracy**
  - **individual mass** measurements
  - EM counterpart is essential to study **binary tidal interactions** → type Ia SN progenitors

- Observations of **ultra-compact DWDs** not detectable by LISA
  → have a more complete view of the whole population
  → insights on stellar and **binary evolution**
  → common envelope, mass transfer

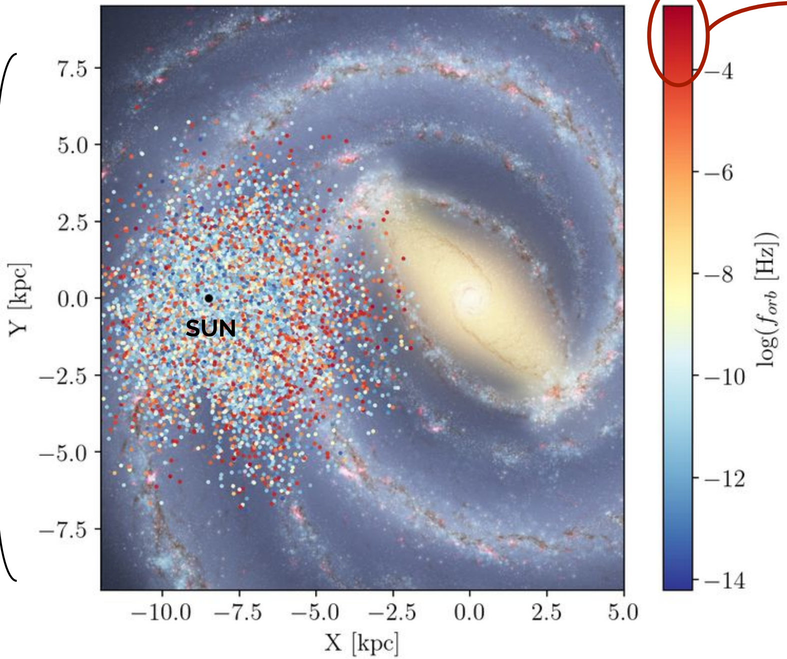
— Multimessenger astronomy for LISA

→ **Goal :** extend the EM catalogue of **LISA double white dwarfs** (DWDs) with systematic surveys

HOW?

We look for **detached ultra-compact DWDs**

Synthetic catalogue of EM observations of **DWDs**, spanning all orbital periods



Ultra-compact DWDs targeted by LISA
→ special evolutionary path (interactions, mass transfer…)
→ clear imprint on mass, age…
→ distinct EM signatures

— Building a synthetic EM catalogue of white dwarfs

same photometric EM emission

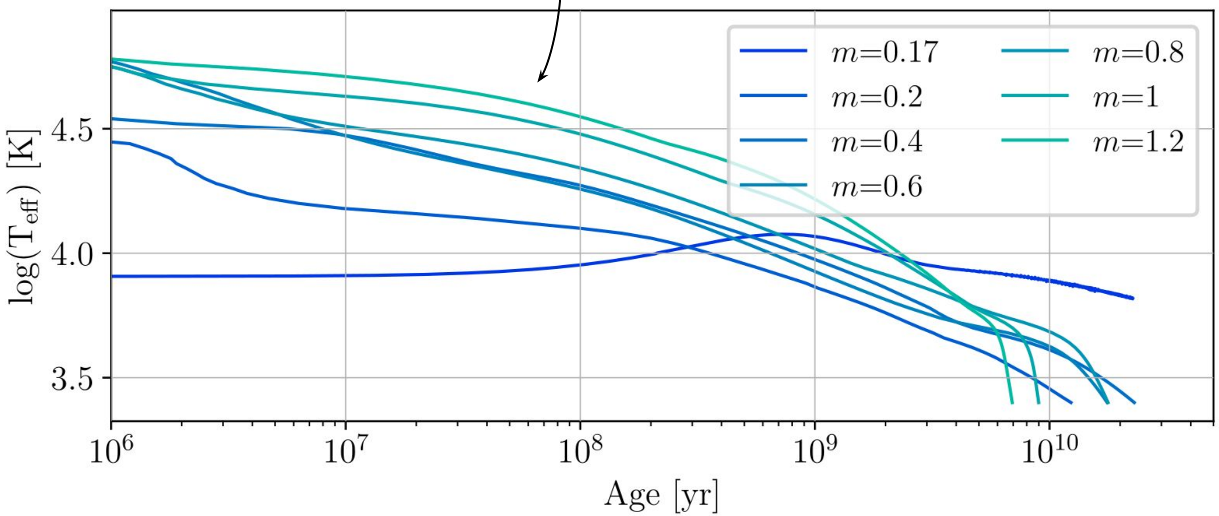
1. Generating a Galactic population of white dwarfs as single stars or in binaries
   → Population synthesis code + semi-analytic model of the Milky Way

2. Computing **photometric magnitudes** using **cooling sequences** for white dwarfs

u, *g*, *r* filters

White dwarf are bright in the **blue** band

Perego et al. 2025



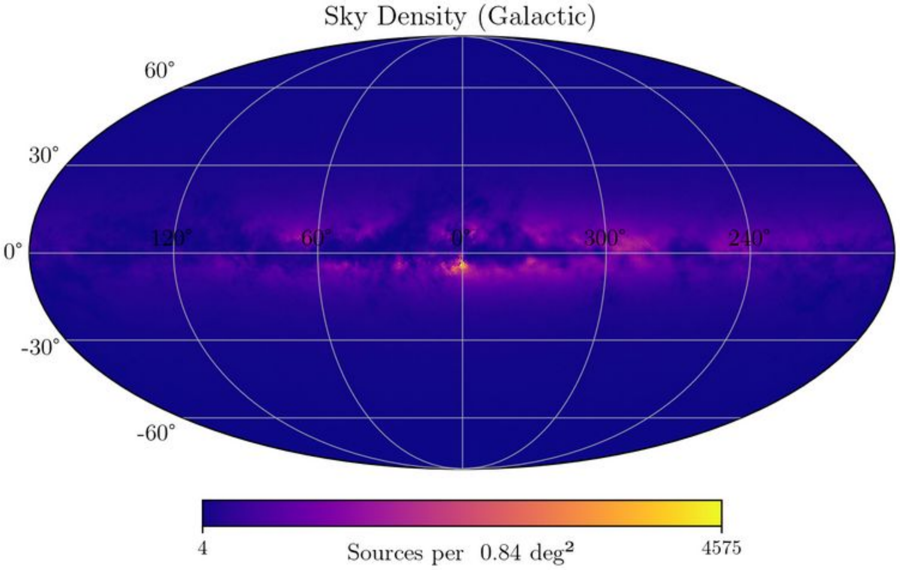
— Building a synthetic EM catalogue of white dwarfs

3. Incorporating **extinction and reddening** from interstellar **dust maps** of the Milky Way

$$u_{obs} = u_{abs} - 5 + 5\log(d) + A_u$$

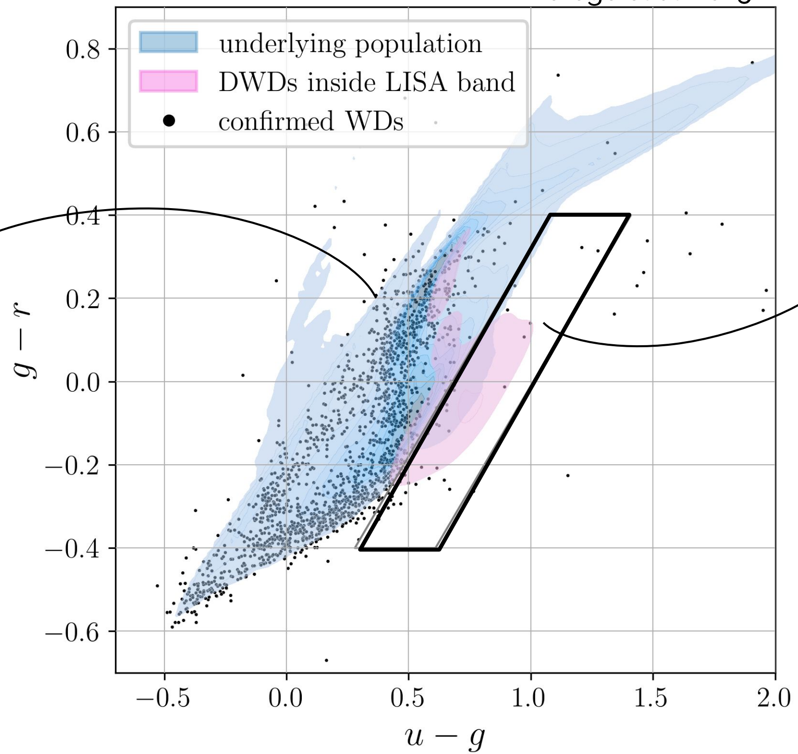
4. Applying a sensitivity limit for the telescope: **observed magnitude *u* lower than ~ 24.5**

deeper than currents surveys (magnitude limit ~22 for SDSS, ~21 for Gaia)



— Results : color-color diagram

Perego et al. 2025



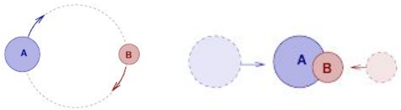
Our synthetic catalogue **aligns** with real WD observations (Gaia / SDSS)

~65%→ LISA candidates
~30% → wider DWDs
~5%→ single WDs

LISA potential sources separate from all other observations of white dwarfs !

we can focus on this area to identify candidates for **subsequent follow-up**

necessary to confirm that they are binaries



— ʻApapane: Dynamic sky across all scales

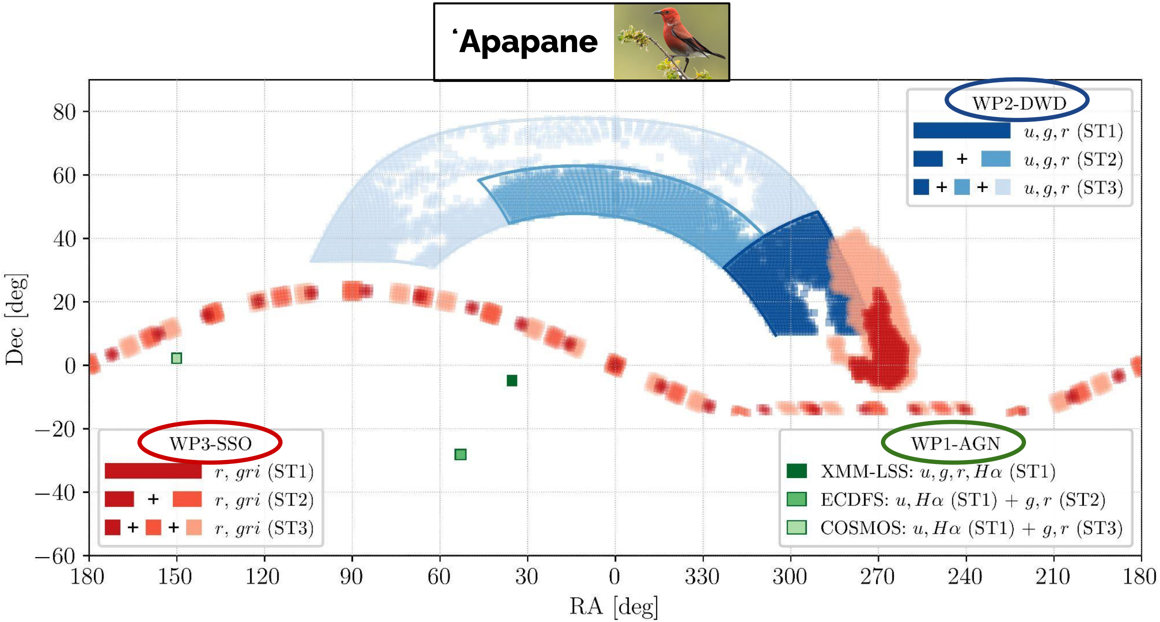
Canada France Hawaii Telescope (CFHT)

3.6-meter telescope with wide-field optical imager **Megacam** → deep in **u-band**

→ call for a Community Survey over 6-year period (2027-2033), offering [400-700] nights

→ submitted proposal including 3 work packages (WPs)

Discovery of small Solar System objects (SSOs), from near-Earth asteroids (NEAs) to inbound interstellar objects (ISOs), to study their physical and dynamical evolution



Deep survey of the Galactic plane, delivering legacy data for binary studies, leveraging a strong synergy with LISA

Monitoring of Active Galactic Nuclei (AGN), serving in designing robust, large-scale AGN surveys with CASTOR mission

— Survey strategy

Observing strategy

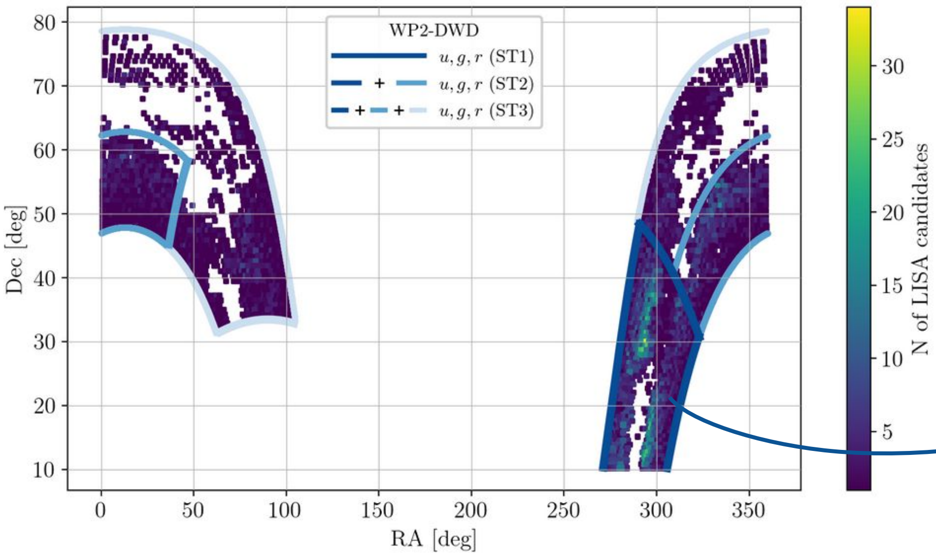
- Single visit in each filter (*u, g, r*)
  to reach different magnitude depths : *u*~24/24.5
- Sky coverage: low-extinction fields in the Galactic plane, divided in tiers of priority

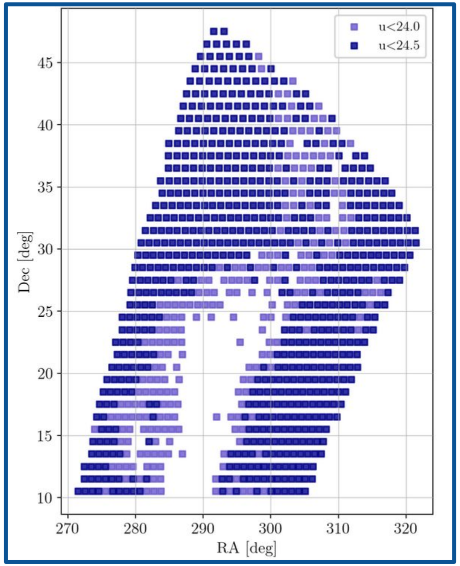
Observing conditions

Good Image quality < 1”

Atmospheric extinction < 0.2

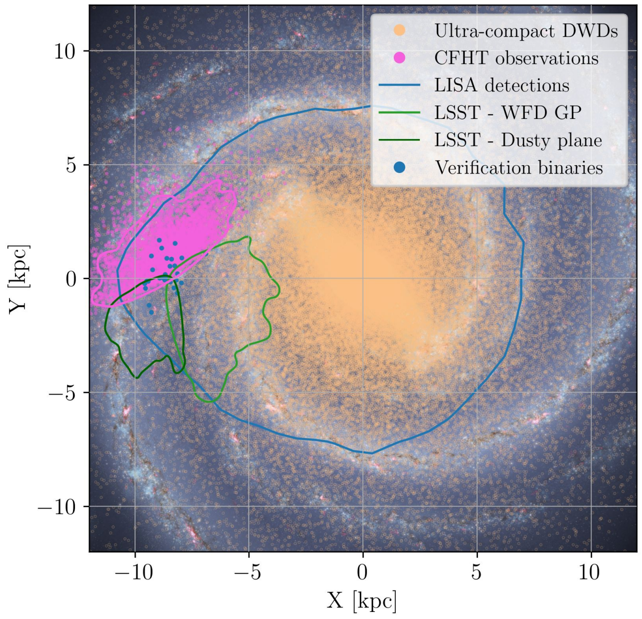
Moon illumination < 25% (*u,g*) ; < 50% (*r*)





— Survey strategy

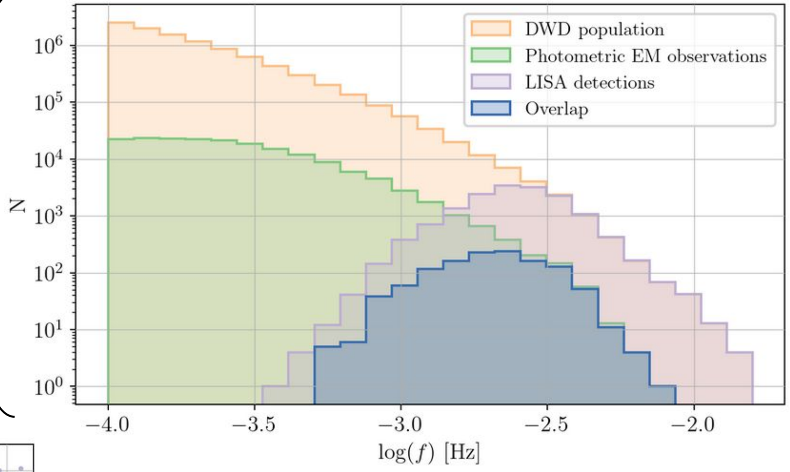
Science Tier	Number of nights	LISA candidates	Objective
ST1	~70	5'000	Max # of LISA candidates (~170 new VBs)
ST2	~130	7'500	studying local space densities in the Galactic plane
ST3	~200	10'000	complete view of the Galactic plane at latitudes within 15°

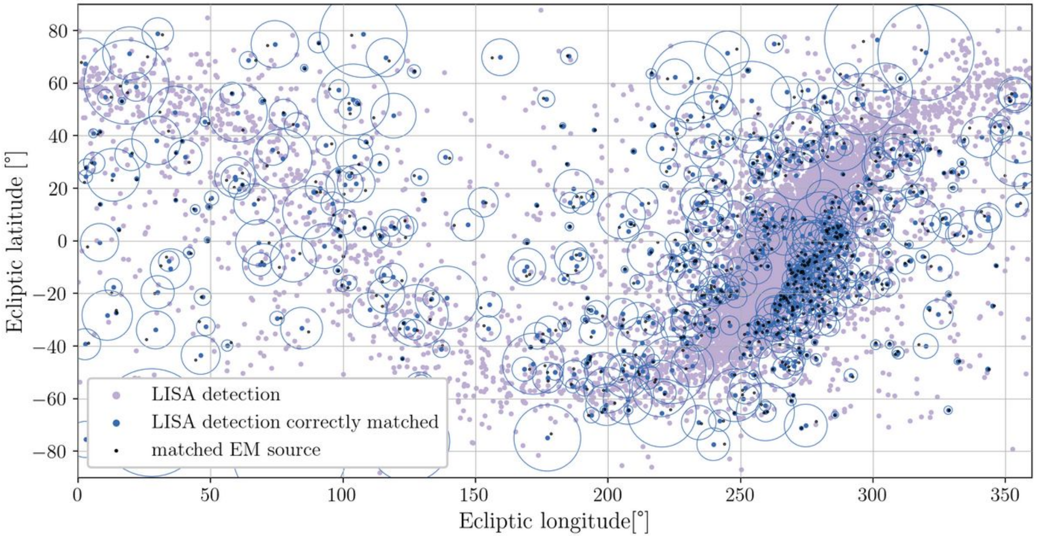


— Next challenges

LISA will deliver ~10 000 GW detections over the whole DWD population

→ challenging to identify correct counterparts in EM observations





Open questions

- Which EM parameters we DO need to better constrain the match?
- At which accuracy?
- Which LISA parameters are the best-suited to maximise the identification?

— Summary

Enabling multimessenger science of Galactic binaries

deep multi-band photometric surveys as CFHT, LSST
to extend the catalogue of WD observations

color selection to **find ultra-compact binaries** over all WDs (Perego+2025)

↓

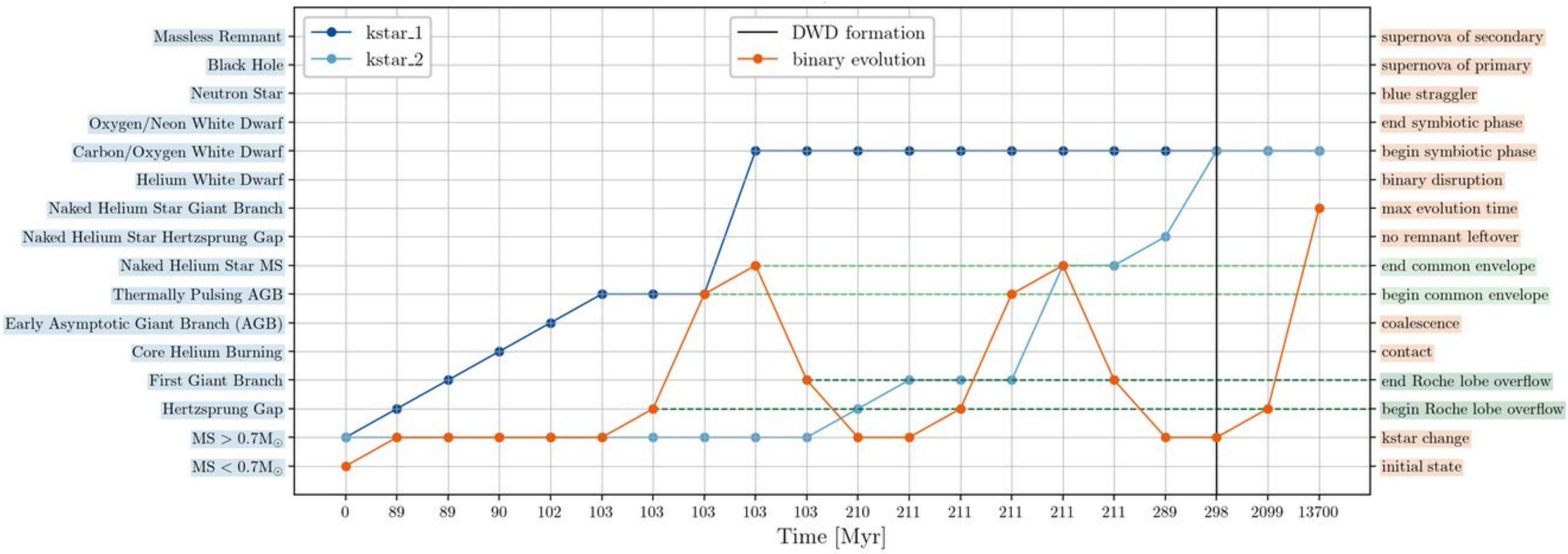
confirm LISA candidates
→ follow-up with spectroscopy/high-cadence photometry

↓

fully characterise them
by determining stellar and orbital parameters
(temperatures, inclination, component masses and radii)
→ combining GW parameters, light curves, time-series / high-resolution spectra

Backup slides

— COSMIC



Initial parameters from multidimensional distributions following Moe & Di Stefano (2017)

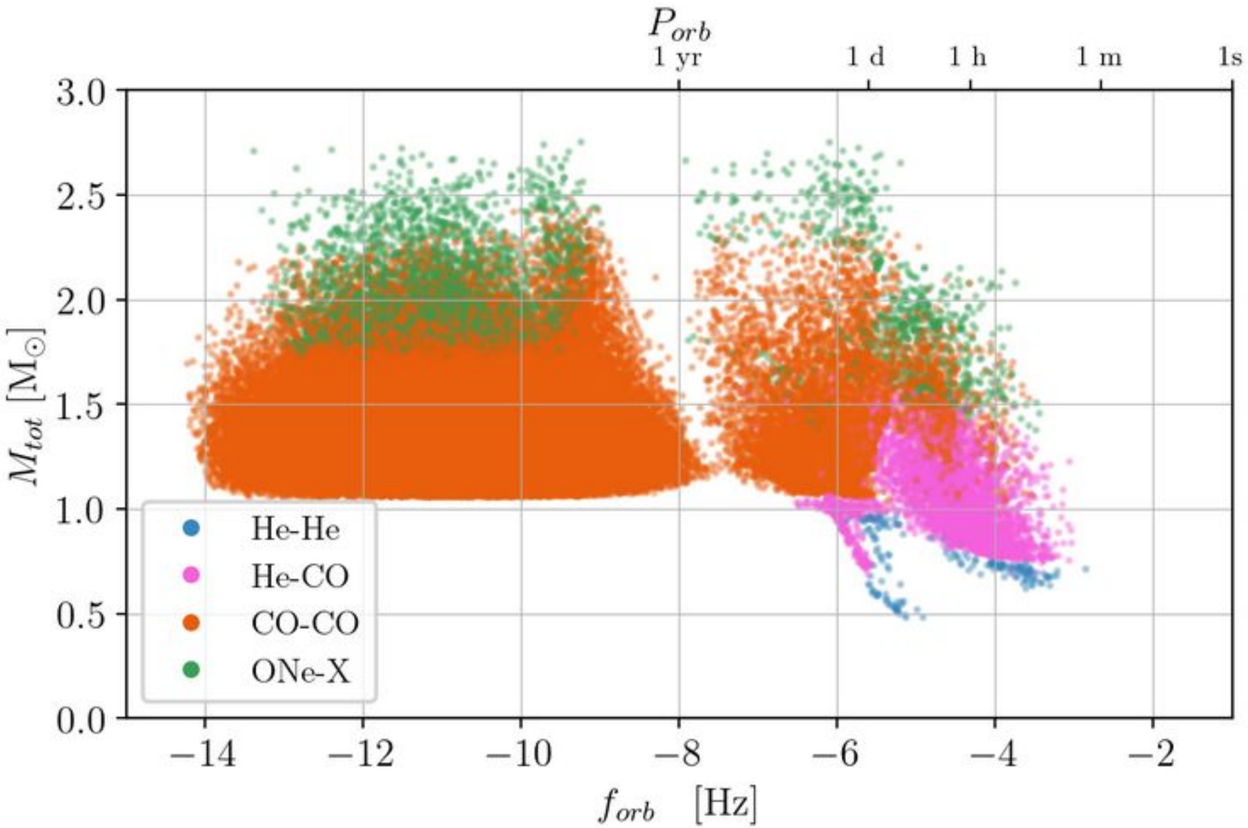
CE efficiency α = 1

Binding energy factor for CE = 0

Critical q from BSE with Hjellming & Webbink, 1987

— Frequency and mass distribution of DWDs from COSMIC

```
Number of binaries that have not merged: 8.74e+08
Number of binaries that have GW frequency > 1e-4 Hz: 1.40e+07
He-He:  756900
He-CO:  11318100
CO-CO:  1119500
ONe-X:  821700
```



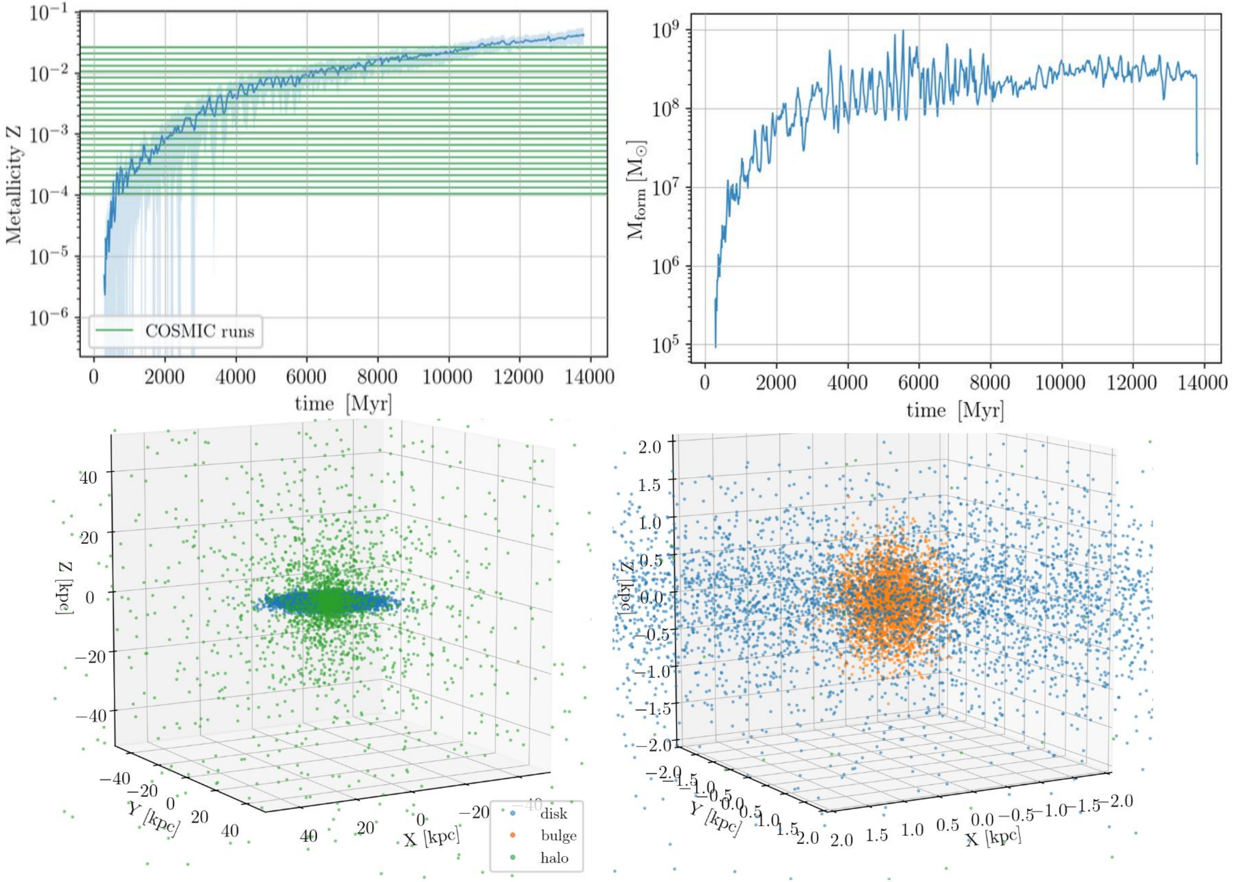
— SFH and Galactic distribution

SFH with metallicity from cosmological simulation + analytic model for the MW structure

- **Halo** (~3%)
  - SF until ~ 2Gyr
  - fraction (in mass) of all WDs now is 15% of the total mass of the stellar halo
  - $\rho_{\mathrm{halo}} \propto (1 + r/a_{0,\mathrm{halo}})^{-3.5}$

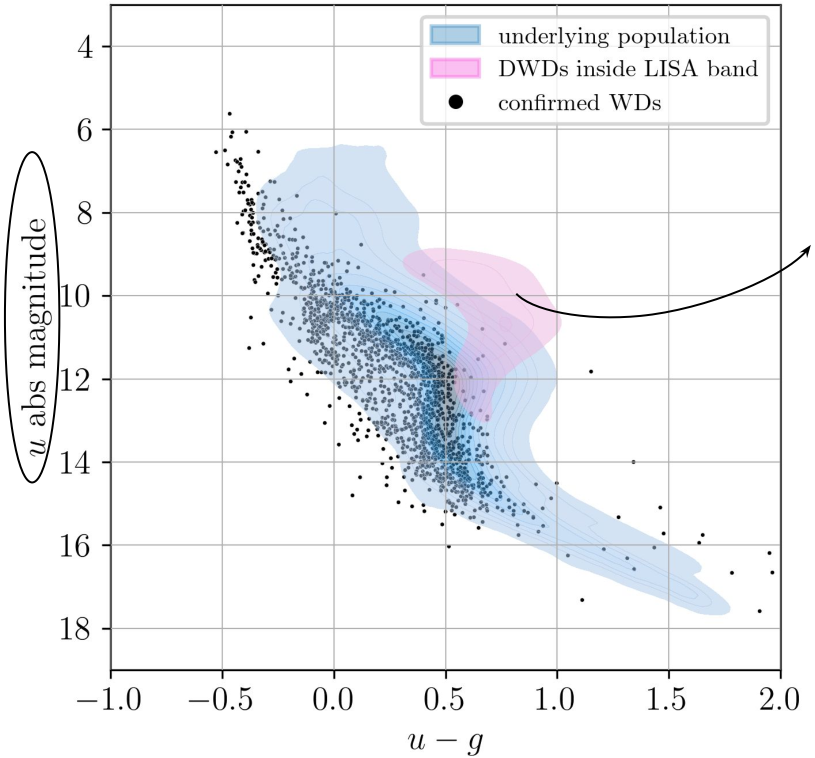
- **Disk** (~65%)
  - SF from ~ 2Gyr up to now
  - $\rho(R, z) = \rho_0 \, \mathrm{e}^{-R/H} \, \mathrm{sech}(z/h)^2$

- **Bulge** (~32%)
  - SF from ~ 2Gyr up to now
  - mass is 50% the mass of the disk
  - $\rho_{\mathrm{bulge}}(r) \propto e^{(r/r_{\mathrm{b}})^2} \ \mathrm{pc}^{-3}$



— Results : magnitude-color diagram

Perego et al. 2025

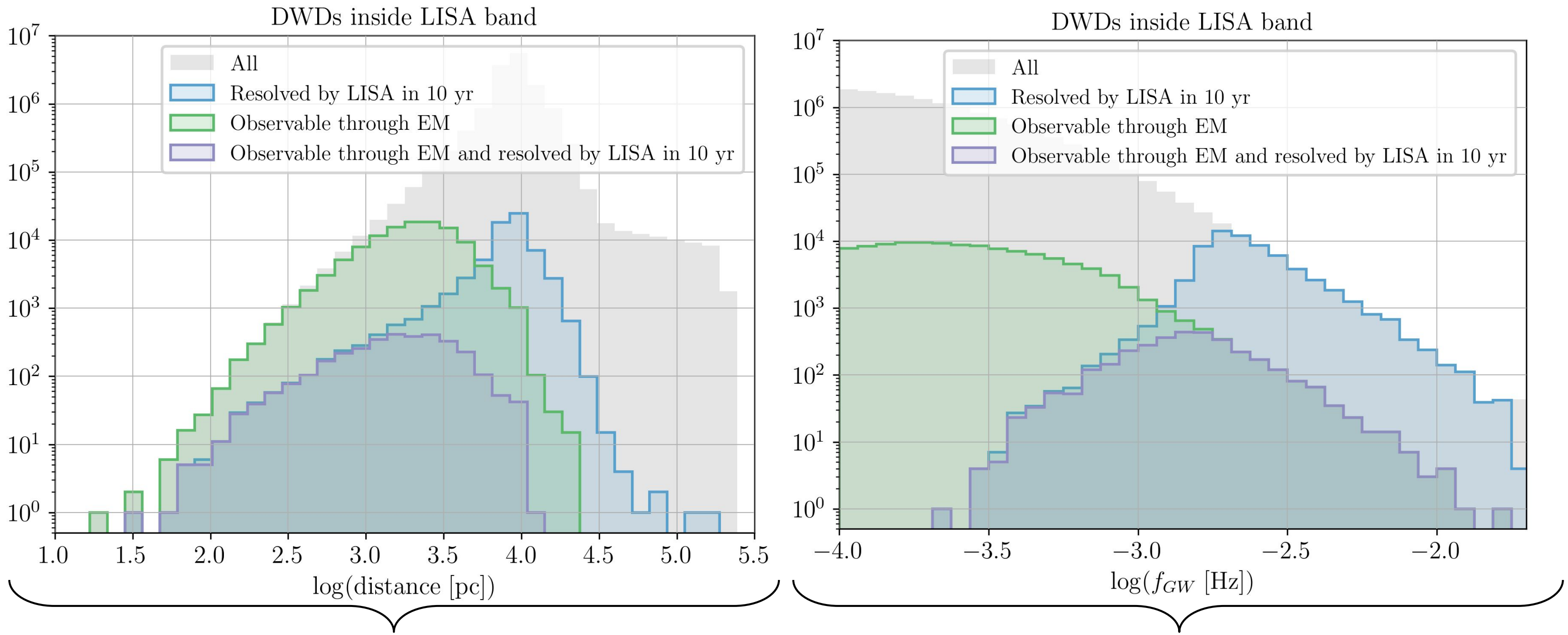


We need the **distance**

$$u_{abs} = u_{app} + 5 - 5\log d$$

LISA potential sources separate from all other observations of white dwarfs !

— LISA and EM sources

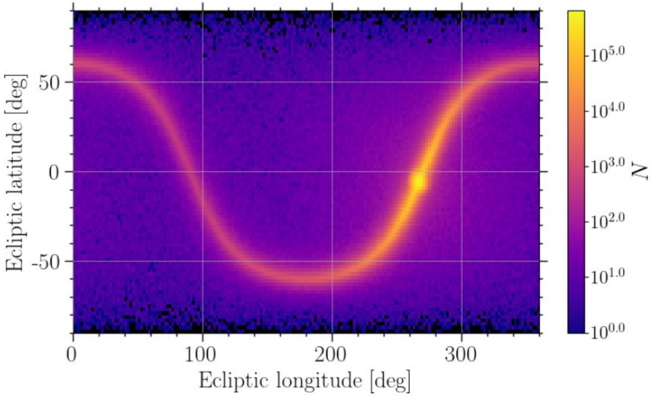


(photometric) EM observations
are the closest ones

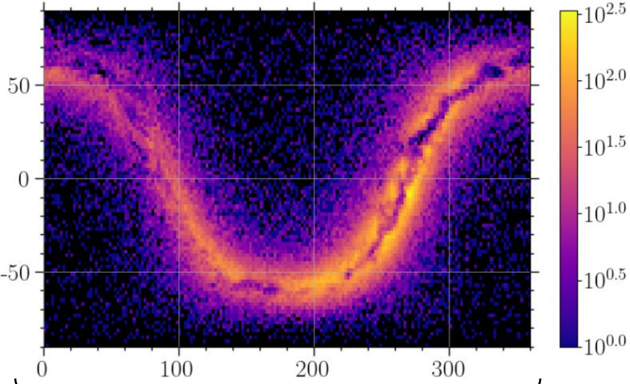
LISA detections
are the high-frequency ones

— Spatial distribution

DWDs inside LISA band

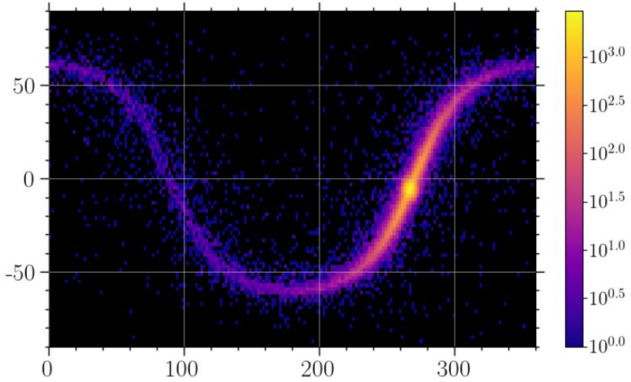


EM observations



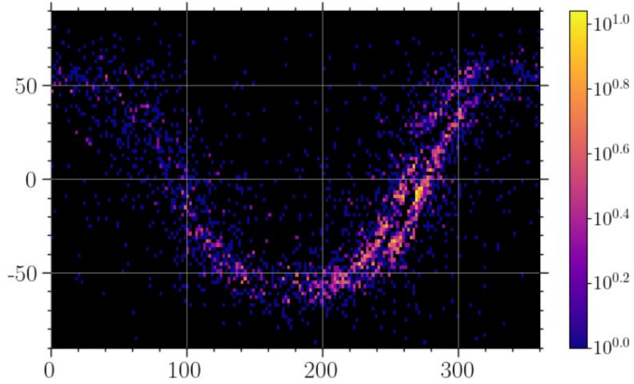
-“more uniform” between disk/halo/bulge
- obscured inner disk
- distance peak at ~ a few kpc

LISA detections



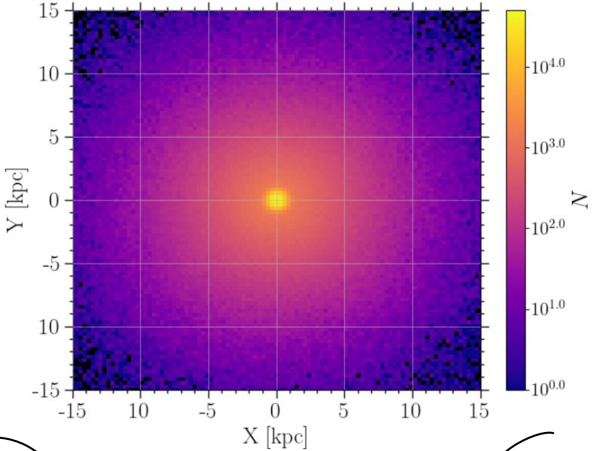
- concentrated in the disk/bulge
- spatial distribution peak at the Galactic center

EM & LISA

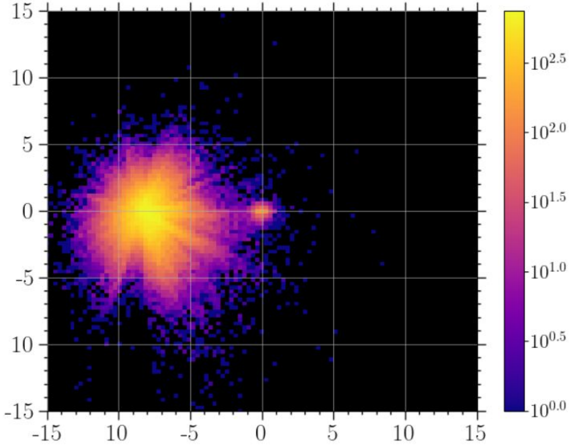


— Spatial distribution

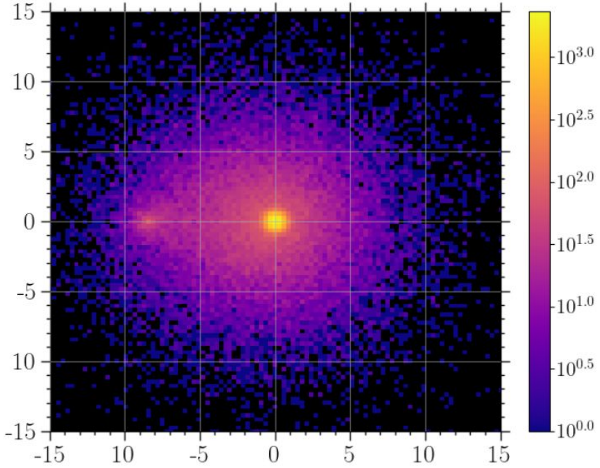
DWDs inside LISA band



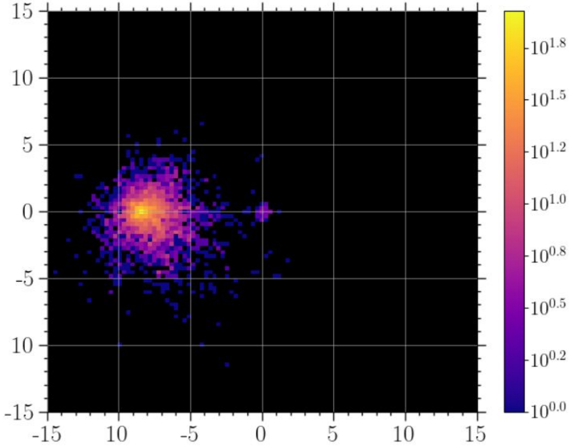
photometric observations



LISA detections

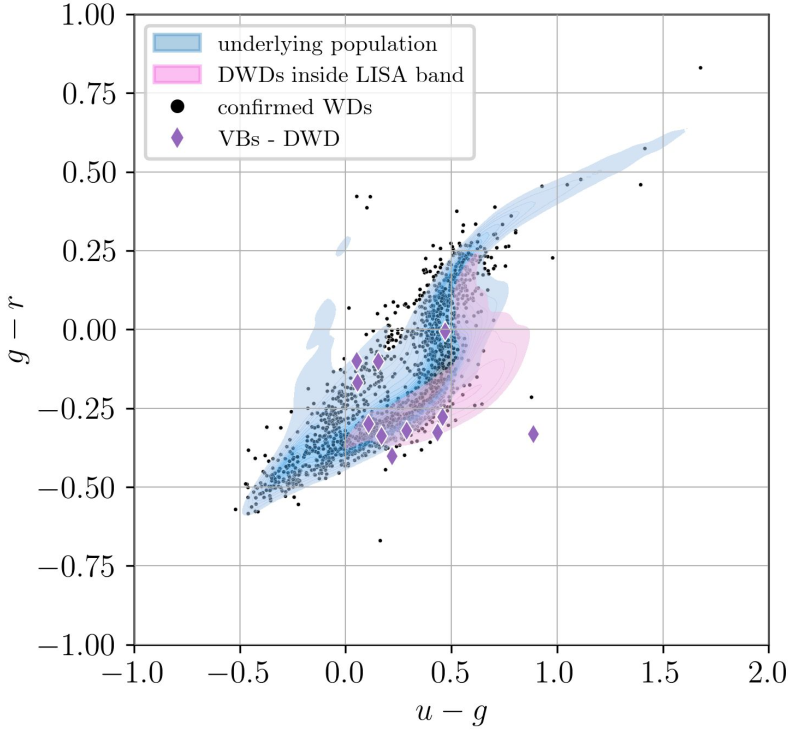


EM & LISA

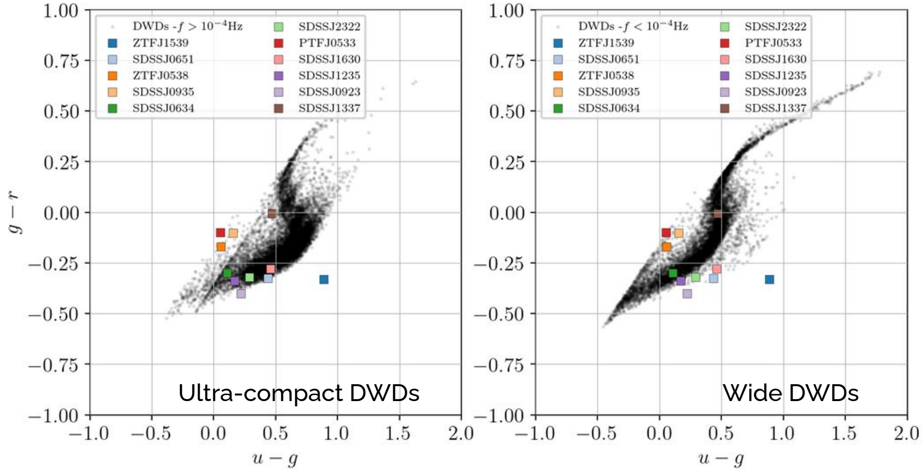


— Verification binaries : detached DWDs

Ultra-compact binaries already discovered by surveys as ZTF and ELM
→ different identification methods, peculiar systems → biased and uncomplete sample

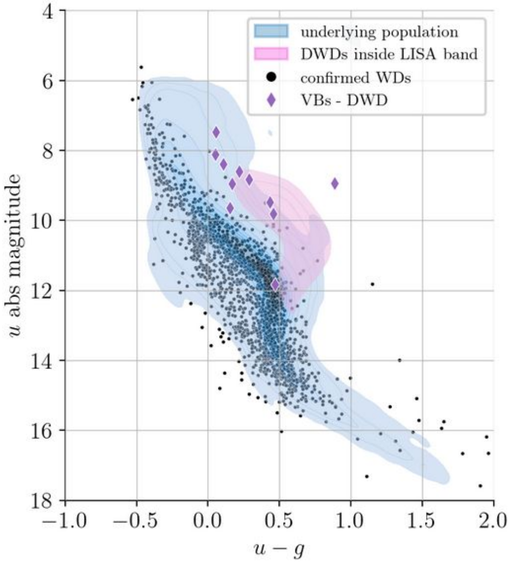


VBs + most of confirmed WDs from Gaia are bright systems
→ *u* apparent mag < 21
→ focus on the brightest EM observations of my dataset

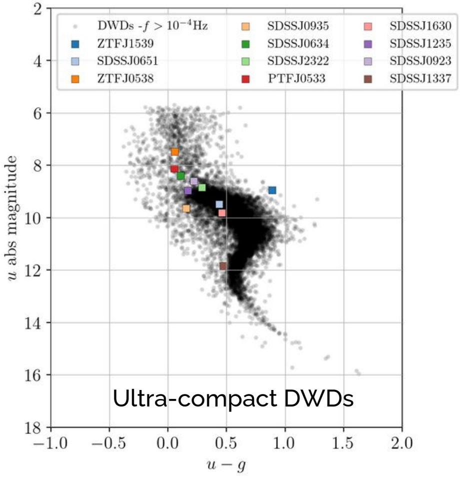


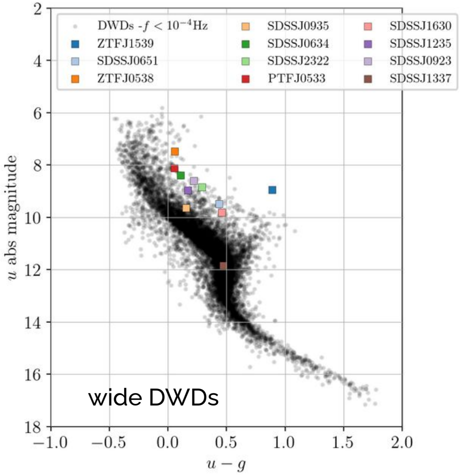
— Verification binaries : detached DWDs

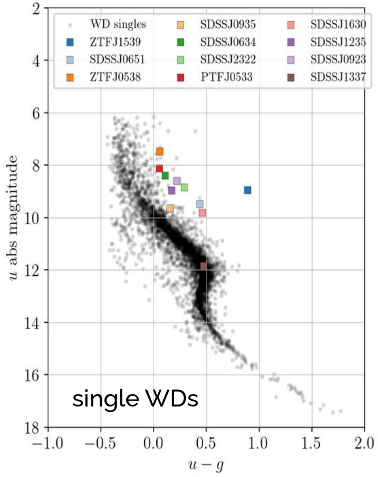
Ultra-compact binaries already discovered by surveys as ZTF and ELM
→ different identification methods, peculiar systems → biased and uncomplete sample



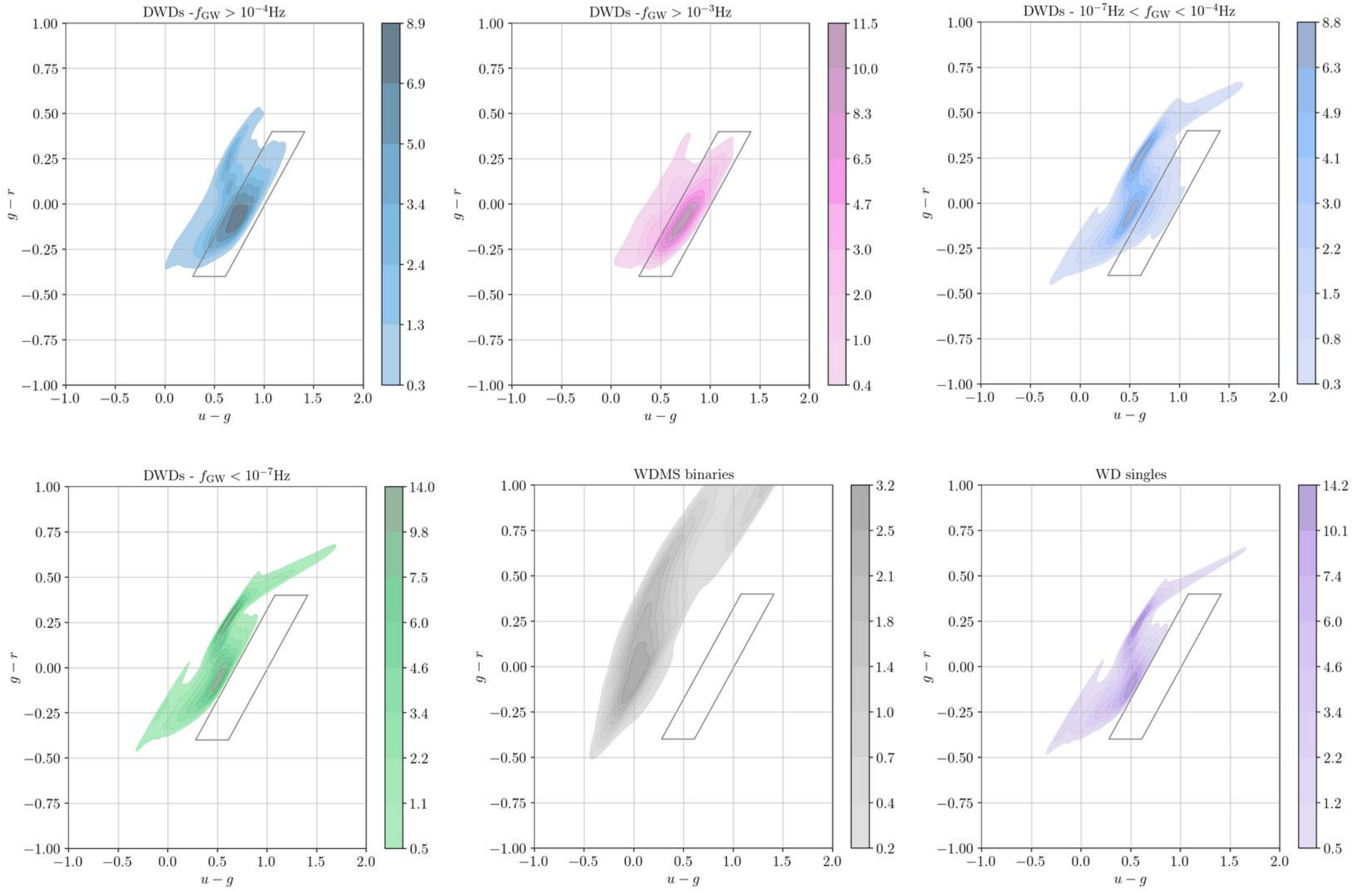
VBs + most of confirmed WDs from Gaia are bright systems
→ *u* apparent mag < 21
→ focus on the brightest EM observations
of my dataset







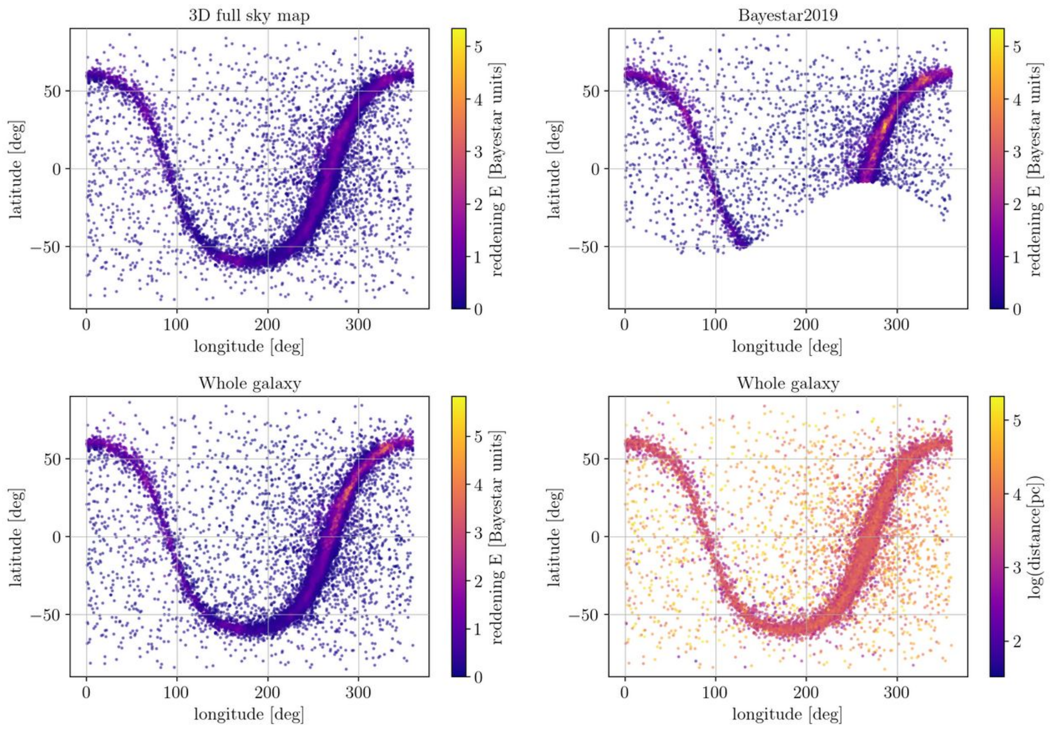
— Density distribution in color/color plot for different WDs classes



— Dust maps

Bayestar map - Green et al. (2019)
A 3D map of dust reddening, covering the three quarters of the sky north of a declination of -30˚, out to a few kiloparsecs. Inferred from stellar photometry of 800 million stars observed by Pan-STARRS 1, and 2MASS photometry for a quarter of the stars, making use also of *Gaia* DR2 parallaxes.

3D full sky map - Dharmawardena et al. (2024)
An all-sky 3D dust density and extinction map out to 2.8 kpc in distance. The input extinction and distance catalogue contains 120 million stars with photometry and astrometry from Gaia DR2, 2MASS and AllWISE.



— Binary systems

White dwarf - white dwarf binaries

Summing the flux of the 2 components :

$f_{tot} = 10^{-0.4m1} + 10^{-0.4m2}$ with $m_{1,2}$ are the absolute magnitude in u, g, r …

Going back to absolute magnitudes :

$m_{tot} = -2.5\log_{10}(f_{tot})$

White dwarf - Main sequence binaries

MS star approximated as black body
→ magnitudes are computed in different bands using filters response curves

Considering only white-dwarf dominated binaries
→ WD is 50% more luminous in bolometric magnitude than the MS star → ~15% of all systems

Computing the magnitude of the total system by summing the fluxes