



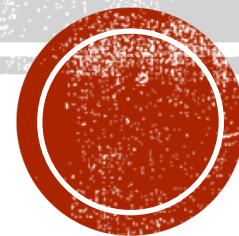
A systematic search for short-period close white dwarf binary candidates based on the Gaia EDR3 catalog and the Zwicky Transient Facility data

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SWIFAR @ YNU



OUTLINE

- I. Background
- II. Target selection from Gaia EDR3
- III. Zwicky Transient facility photometry
- IV. Results
- V. Summary



Background

Close White Dwarf Binaries (CWDBs)

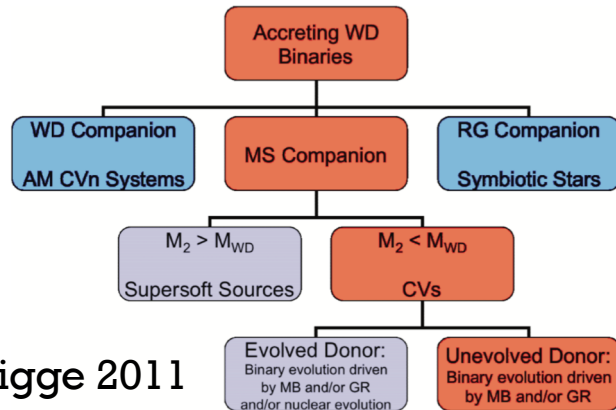
At least one of the components in the close binary systems is a white dwarf.

1. Post Common Envelope Binaries (PCEBs)

These systems consist of a white dwarf and a main sequence star, and they are either detached or semi-detached binary systems.

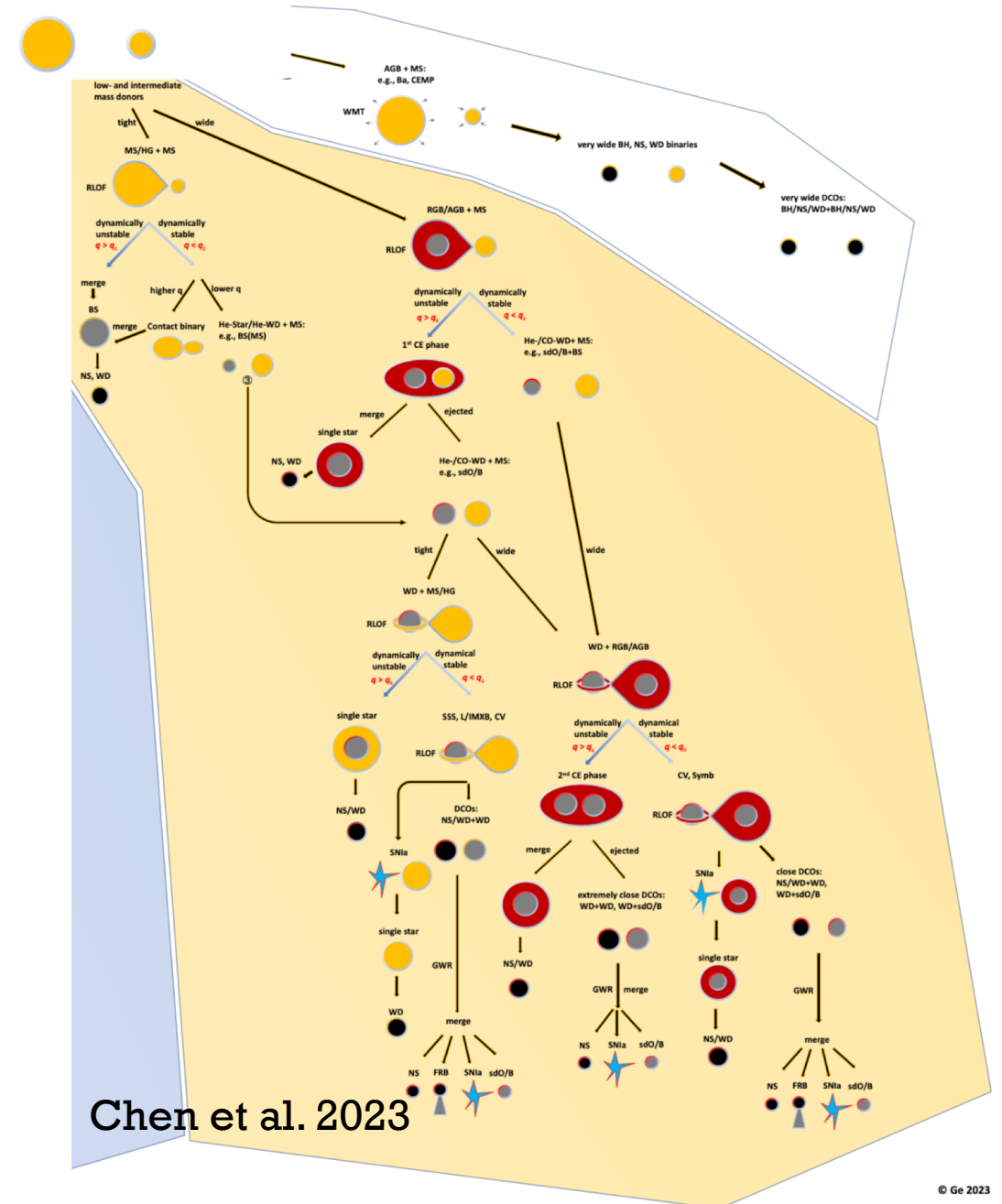
2. Cataclysmic Variables (CVs)

Semi-detached binary systems where the white dwarf is accreting material from its companion star.



3. Double White Dwarfs (DWDs)

binary evolution 25% (Ren et al. 2020)

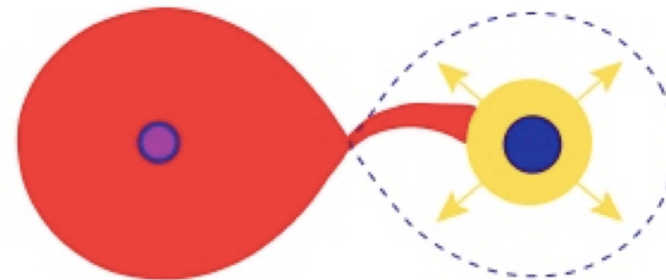


Background

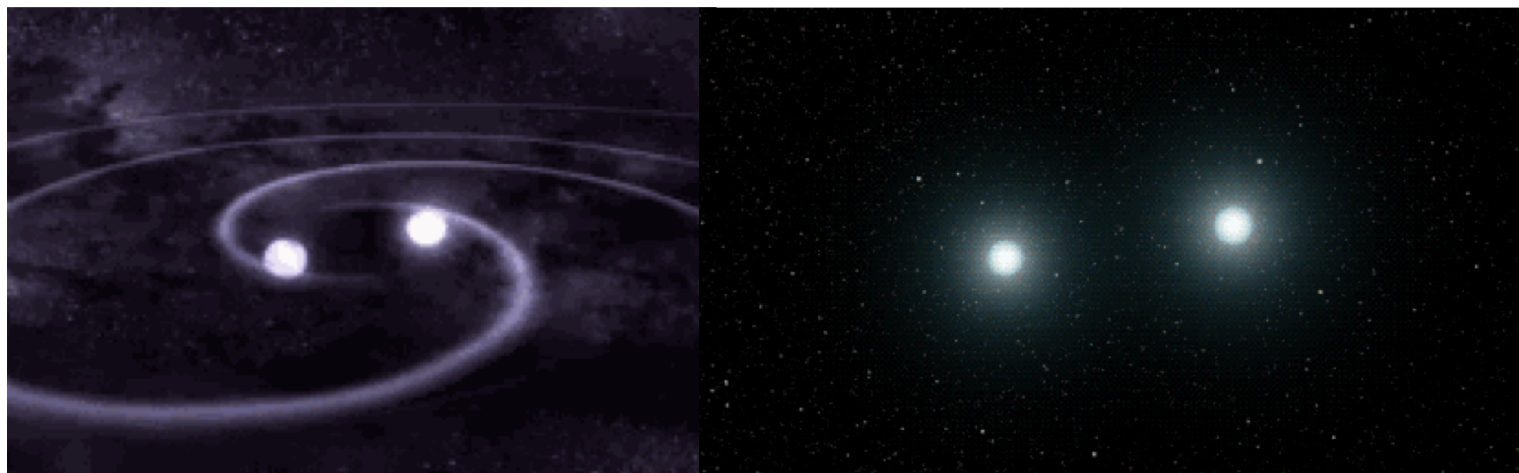
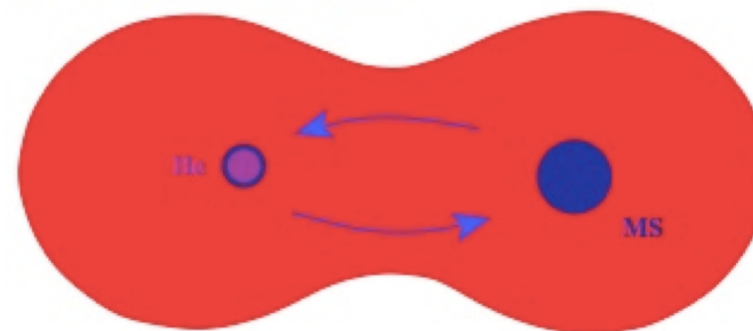
Close White Dwarf Binaries (CWDBs)

- Significances
 - An important branch of the evolution channel of main-sequence star binaries
 - Observational evidence for the binary evolution models
 - Research of stellar physics, milli-Hertz gravitational-wave astronomy (verification binaries for TianQin and LISA), and Galactic evolution
- A search for CWDBs from a combination of Gaia EDR3 and ZTF DR8.

unstable RLOF $\longrightarrow$ dynamical mass transfer

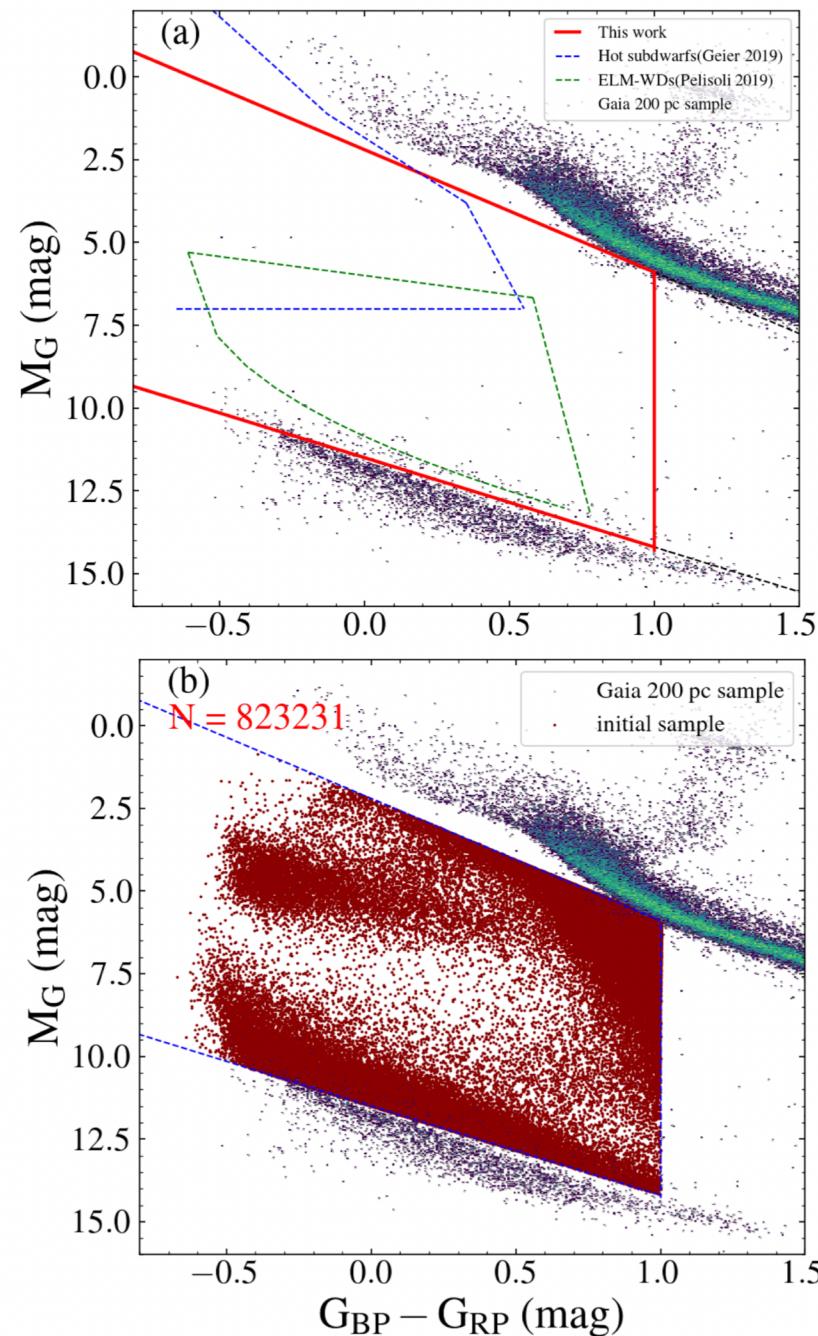


common-envelope phase



Target selection from Gaia EDR3

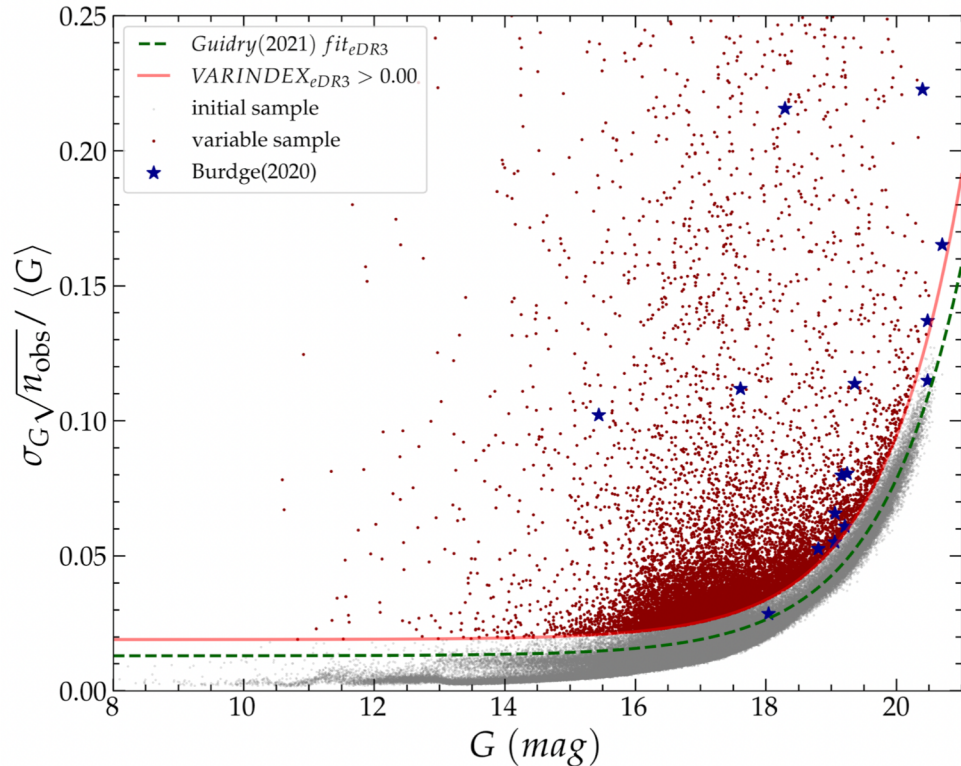
```
SELECT *
FROM gaiaedr3.gaia_source
WHERE dec > -28.0
AND bp_rp < 1.0
AND parallax_over_error > 5
AND phot_bp_mean_flux_over_error > 10
AND phot_rp_mean_flux_over_error > 10
AND 5+5 * log10((parallax + 0.029)/1000) + phot_g_mean_mag > 3.7 * bp_rp + 2.2
AND 5+5 * log10((parallax + 0.029)/1000) + phot_g_mean_mag < 2.7 * bp_rp + 11.5
AND phot_bp_rp_excess_factor < 1.45+0.06 * power
    (phot_bp_mean_mag---phot_rp_mean_mag, 2)
AND phot_bp_rp_excess_factor > 1.0+0.015 * power
    (phot_bp_mean_mag---phot_rp_mean_mag, 2)
AND (astrometric_chi2_al / (astrometric_n_good_obs_al---5) < 1.44
OR astrometric_chi2_al / (astrometric_n_good_obs_al---5) < 1.44 * exp(- 0.4 * (phot_g_mean_mag---19.5)));
```



Target selection from Gaia EDR3

- Gaia Variability Metric
 - The G-band photometries to further filter candidate with Gaia variability metric; Mowlavi et al. (2021)

$$V_G = \frac{\sigma_G}{\langle G \rangle} \sqrt{n_{\text{obs}}}$$



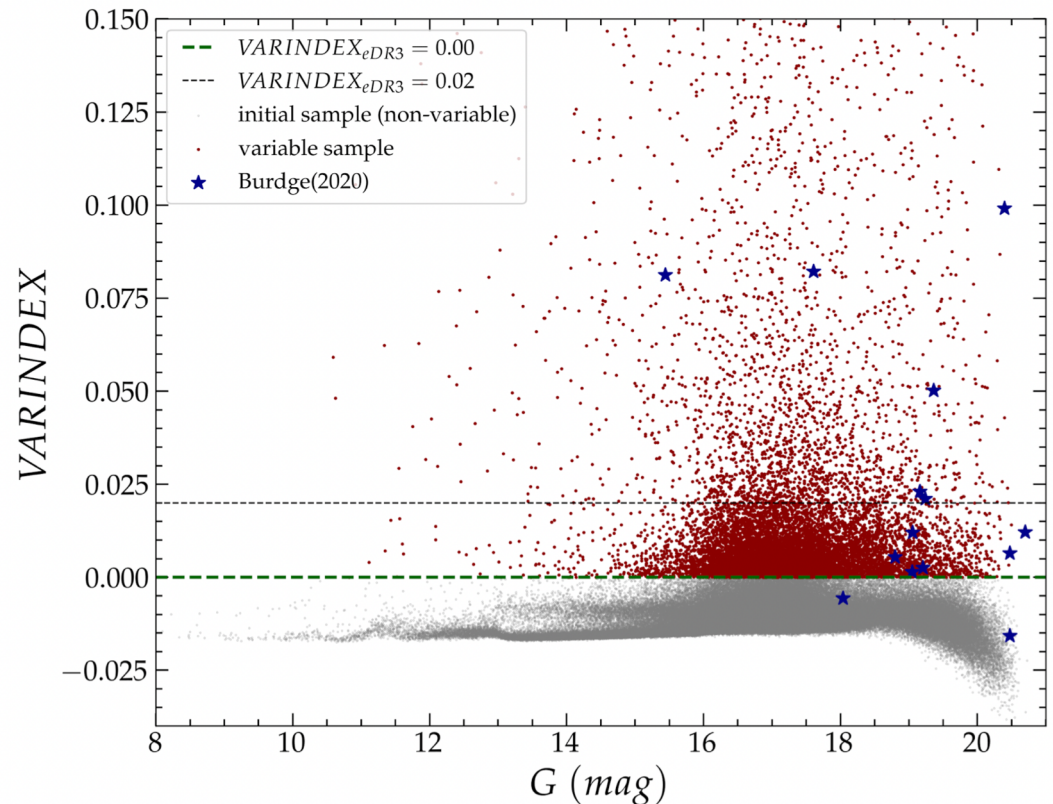
- the Gaia variability metric is actually dependent on the G-band magnitude

● VARINDEX

- In order to select the most probable variable sources from the initial sample
- Define the VARINDEX; Guidry et al. (2021)

$$\text{VARINDEX} = V_G - (Ae^{\alpha G} + Be^{G-17.0} + C)$$

$A = 8.31 \times 10^{-9}$, $\alpha = 0.794$, $B = 0.0005$, and $C = 0.00962$



Zwicky Transient facility photometry

- ZTF DR8
- Period finding algorithms
 1. the Lomb-Scargle (LS) periodogram
 2. the conditional entropy algorithm
 3. the box-least squares (BLS) algorithm

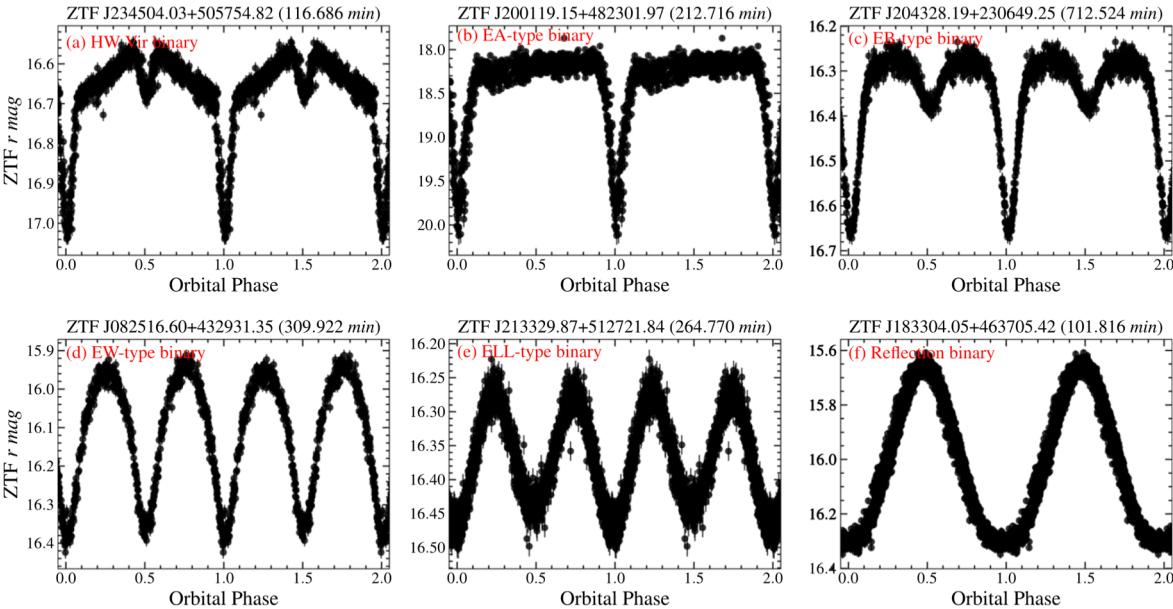
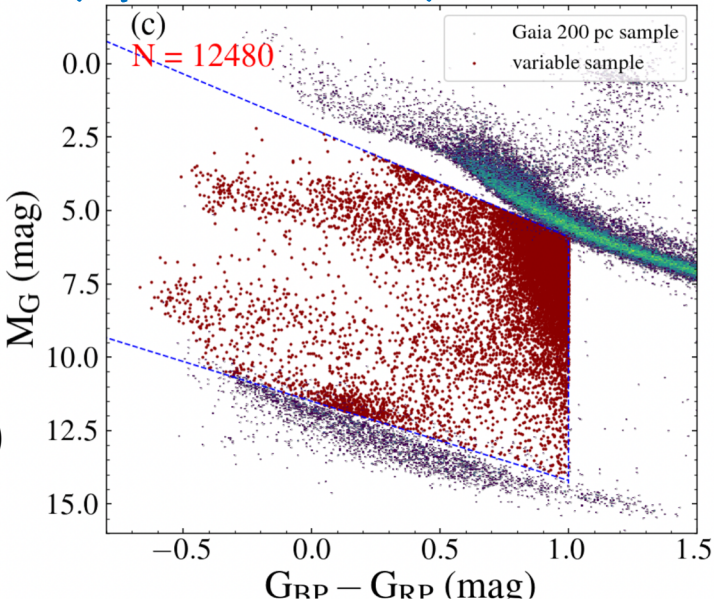


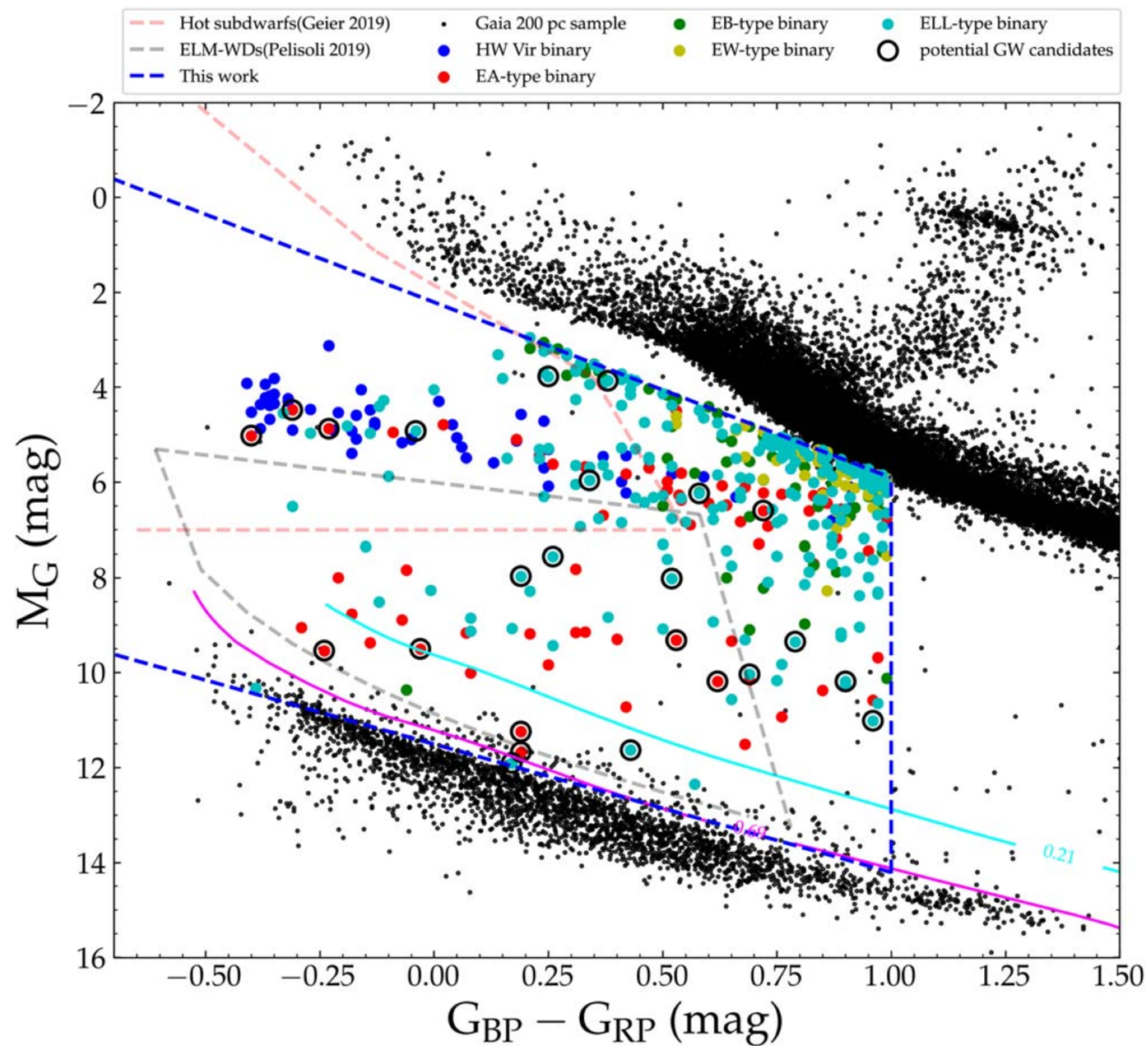
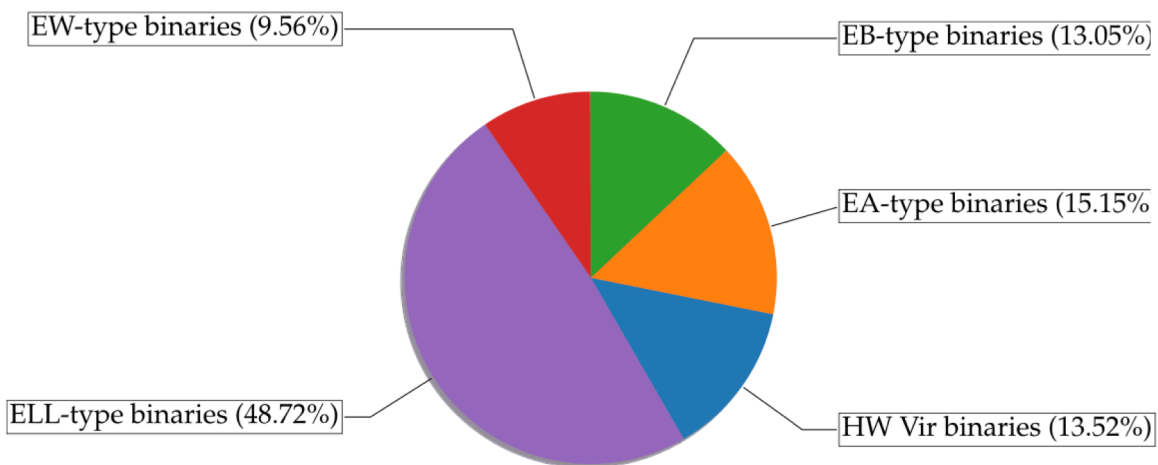
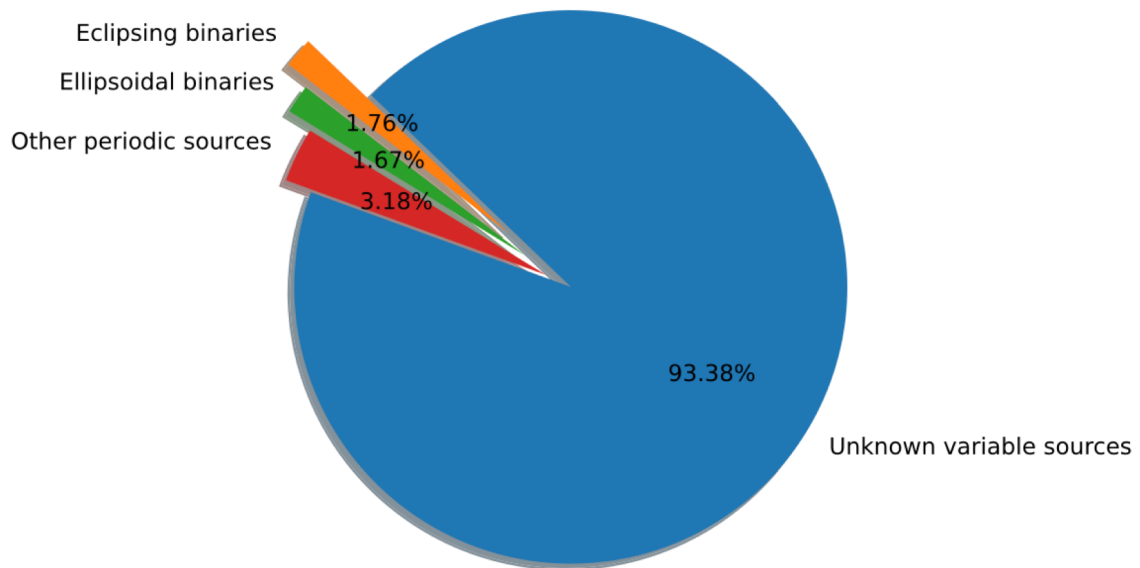
Table 1
Summary of the Numbers of Close White Dwarf Binary Candidates at Different Stages and Different Types

Sample	Type	Identified Sources	Unidentified Sources	Number
<i>Selection on Gaia data</i>				
Initial sample	...	...	...	823,231
Variable sample	...	...	...	12,480
<i>Selection on ZTF data</i>				
Periodic sample	...	...	...	826
Binary sample	HW Vir-type (Algol-type) binaries	6	52	58
	EA-type (Detached Algol-type) binaries	14	51	65
	EB-type (β Lyrae-type) binaries	3	59	56
	EW-type (W Ursae Majoris-type) binaries	1	40	41
	ELL-type (Ellipsoidal) binaries	20	183	209
Subtotal		44	385	429



Results

● Binary sample



Results

- Characteristic GW strain and SNR of GW signals

- The amplitude of the gravitational wave signal

$$\mathcal{A} = \frac{2(G\mathcal{M})^{5/3}}{c^4 d} (\pi f)^{2/3}$$

$$\mathcal{M} = (m_1 m_2)^{3/5} (m_1 + m_2)^{-1/5}$$

- The characteristic strain

$$h_c = \sqrt{N_{\text{cycle}}} \mathcal{A} \quad N_{\text{cycle}} = f_{\text{GW}} T_{\text{obs}}$$

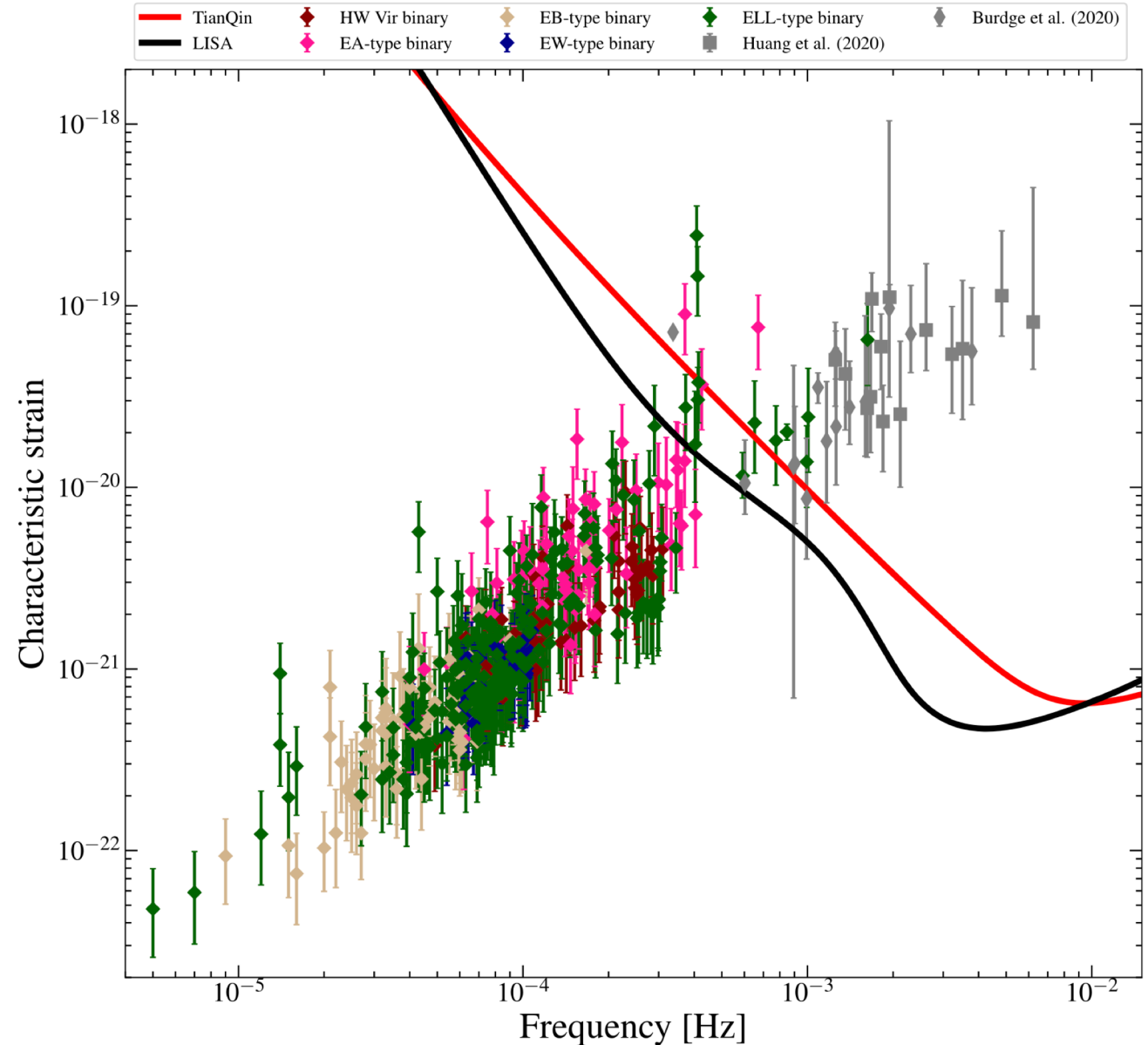
- The SNR (ρ)

$$\rho^2 = \frac{2\langle A^2 \rangle T_{\text{obs}}}{\tilde{S}_n(f_s)}$$

$$\langle A^2 \rangle = \mathcal{A}^2 [(1 + \cos^2(\iota))^2 \langle F_+^2 \rangle + 4 \cos^2(\iota) \langle F_\times^2 \rangle]$$

1. 10 candidates fall above the TianQin sensitivity curve, and about 16 candidates fall above the LISA sensitivity curve.

2. A low SNR threshold of 5 as the minimum standard for GW signals; for TianQin, 2 new VBs; for LISA, 6 new VBs.



Summary

- They crossmatched the Gaia EDR3 and Zwicky Transient Facility public data release 8.
- They applied period finding algorithms to obtain a sample of periodic variables.
- The phase-folded light curves were inspected, and finally they obtained a binary sample containing 429 CWDB candidates.
- They further classified the samples into eclipsing binaries (including 58 HW Vir-type binaries, 65 EA-type binaries, 56 EB-type binaries, and 41 EW-type binaries) and ellipsoidal variations (209 ELL-type binaries).
- They found two (six) potential GW candidates with S/N s greater than 5 in the nominal mission time of TianQin (LISA), which increases the total number of candidate VBs for TianQin (LISA) to 18 (31).



THANKS

