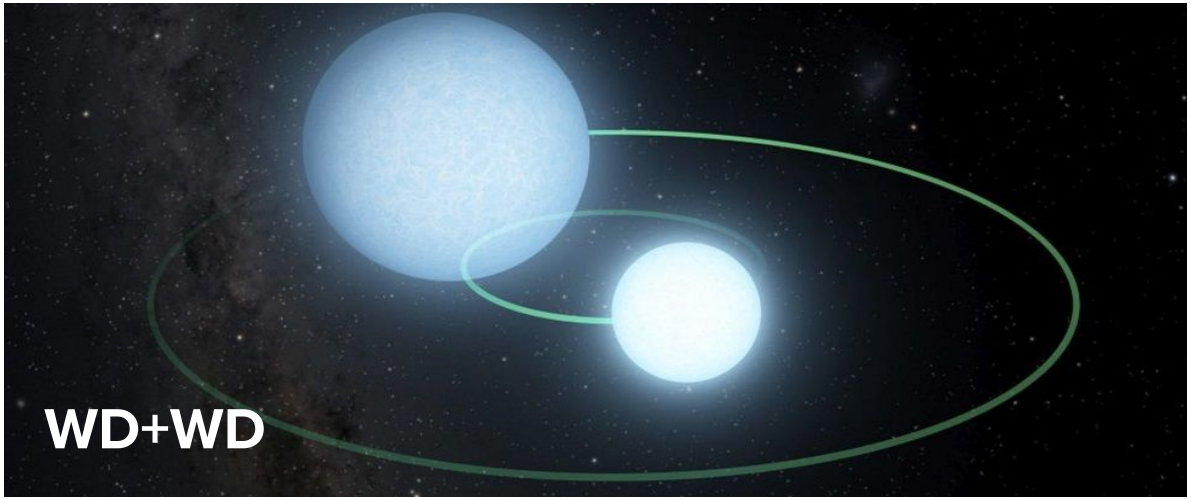
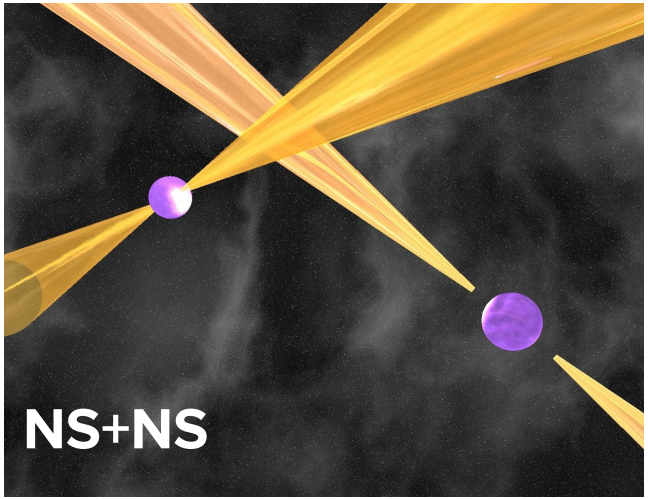
LGWA sources in our backyard

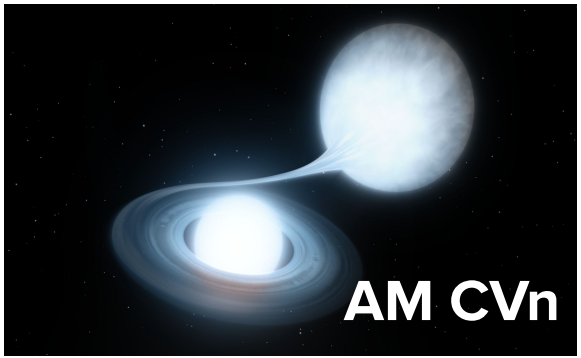
Valeriya Korol, Max Planck for Astrophysics (Garching)

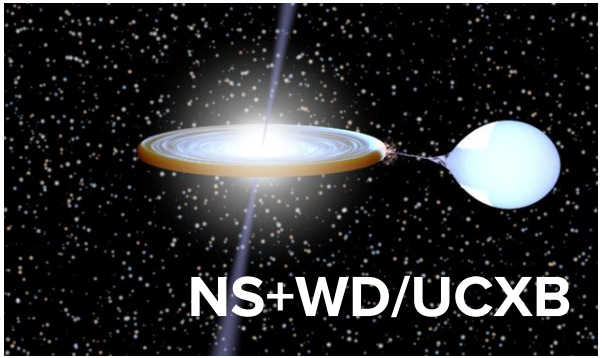
Apollo 17 astronaut Harrison “Jack” Schmitt, the only geologist to walk on the Moon (so far)
Image credit: NASA

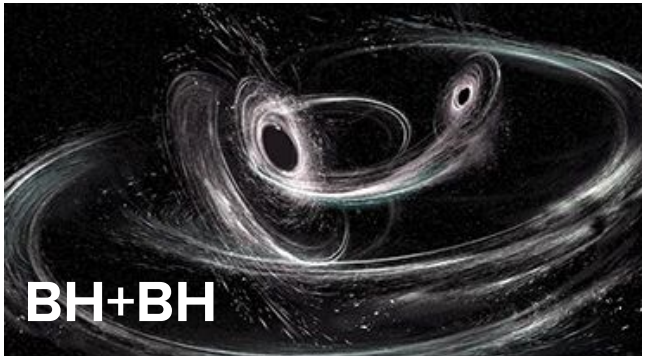
Zoo of GW sources in our backyard



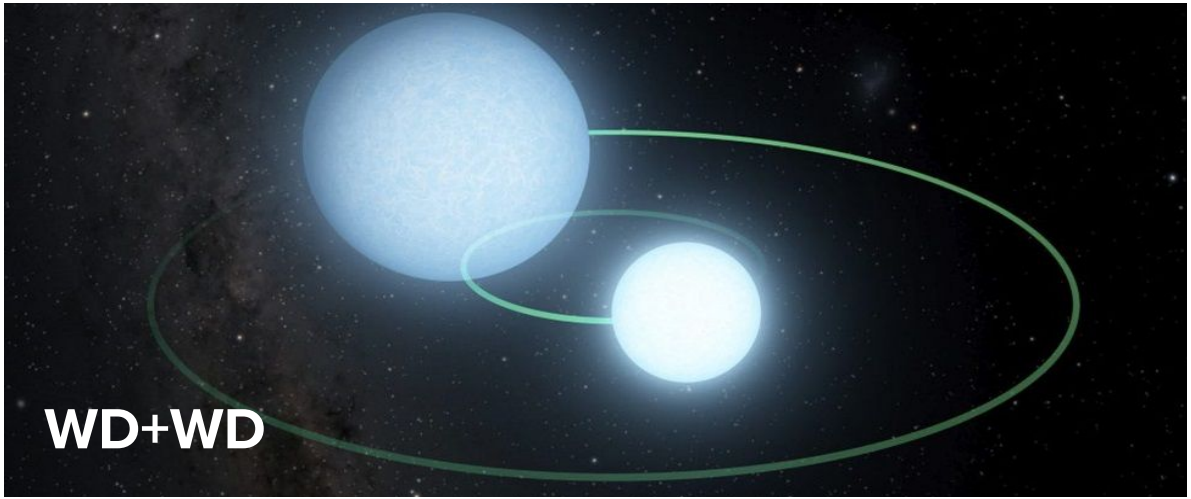


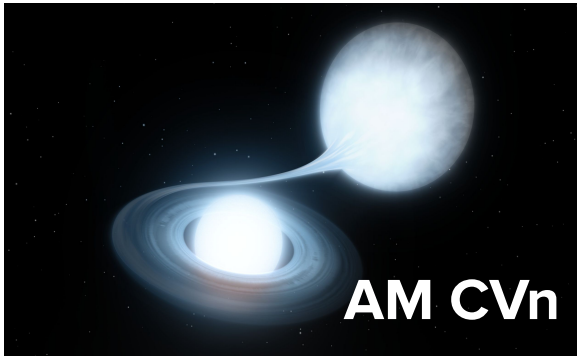


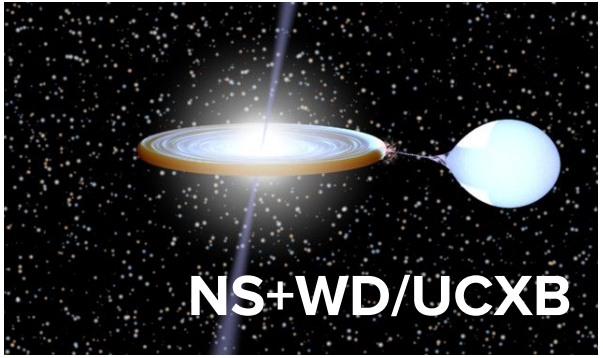




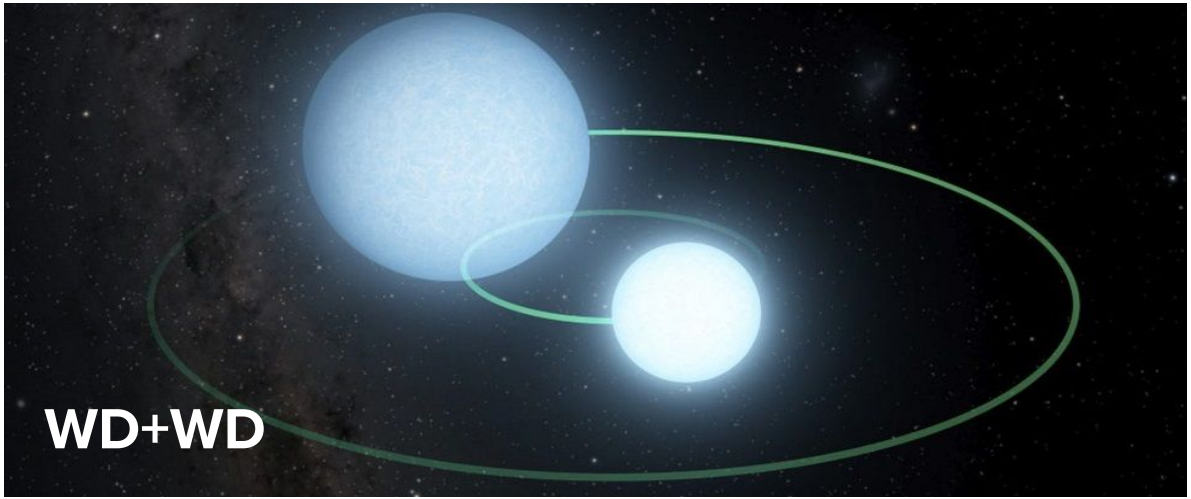
Galactic WD+WD/NS binaries

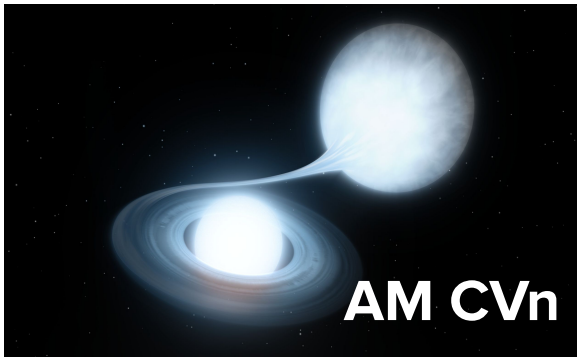


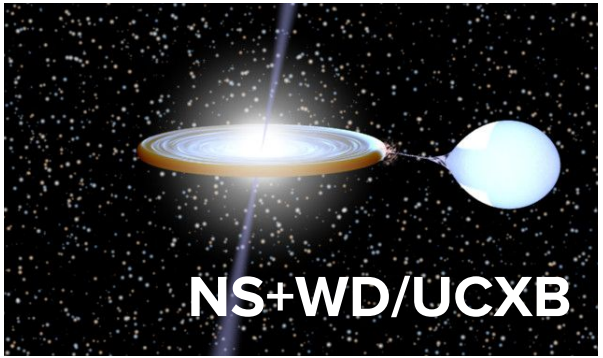




Galactic WD+WD/NS binaries

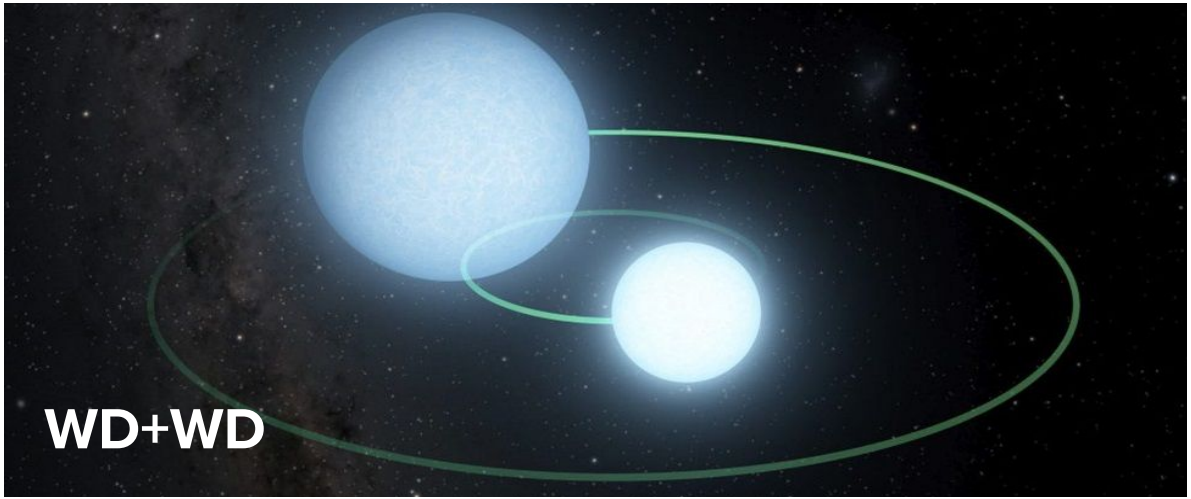


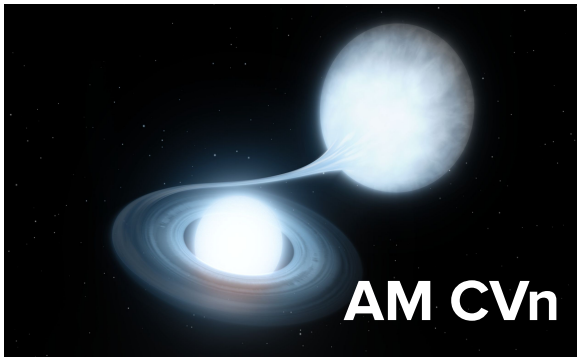


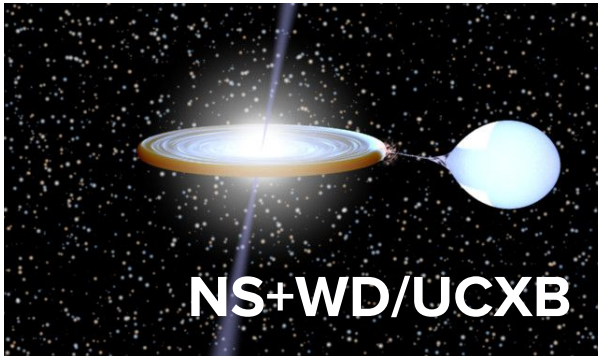


Why they are important for space-based GW astronomy?

Galactic WD+WD/NS binaries

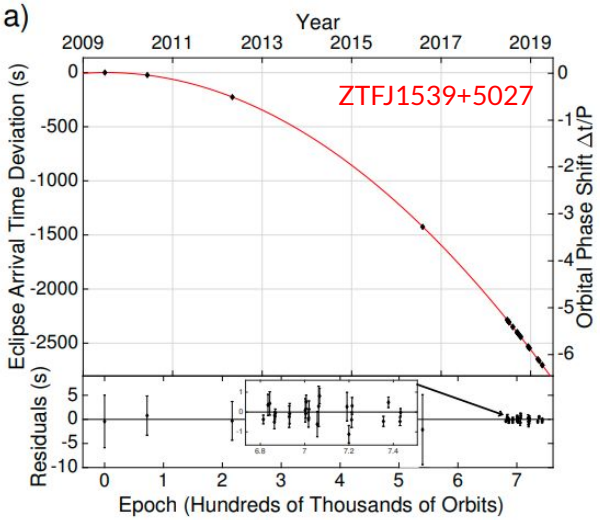






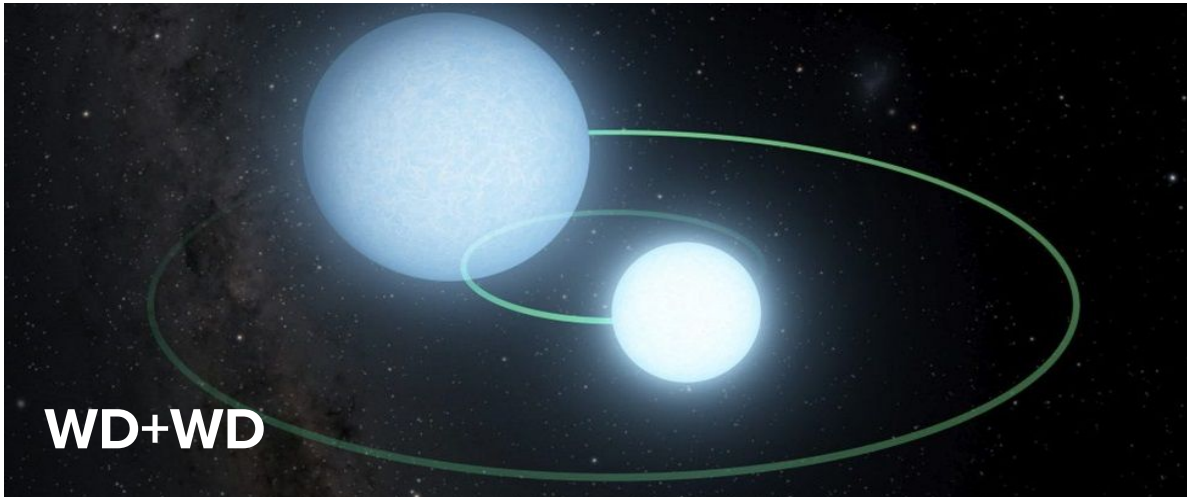
Why they are important for space-based GW astronomy?

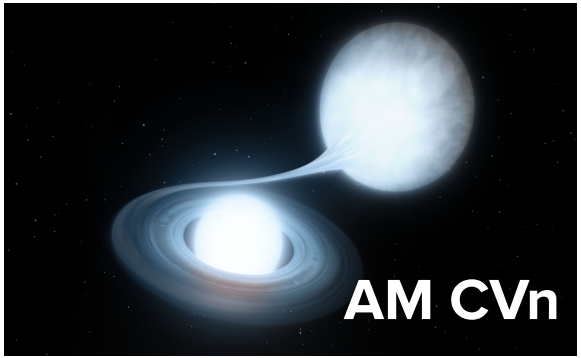
- Guaranteed GW sources

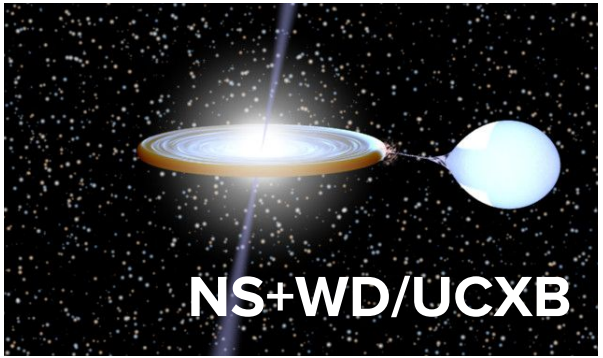


Burdge et al. 2019

Galactic WD+WD/NS binaries

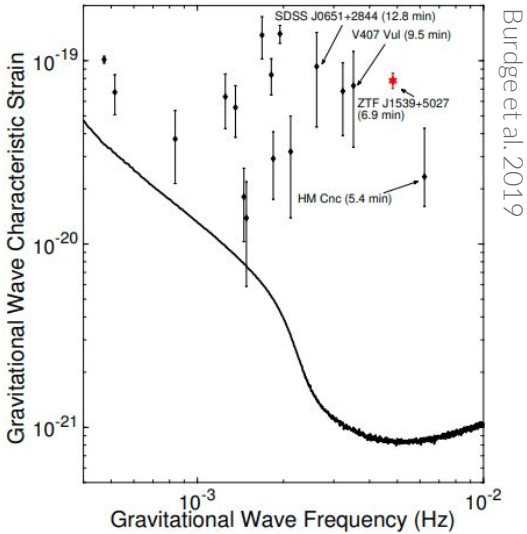




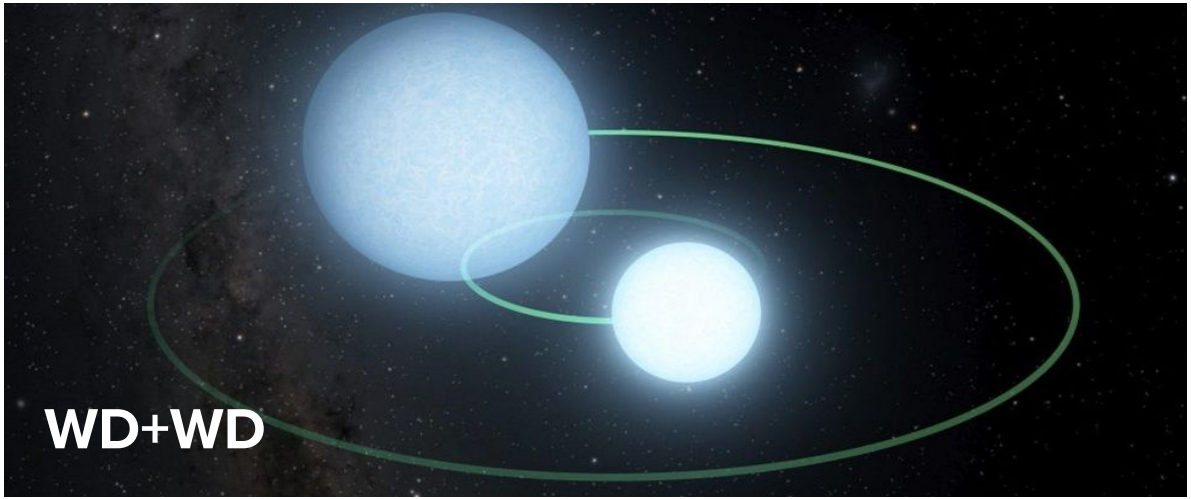


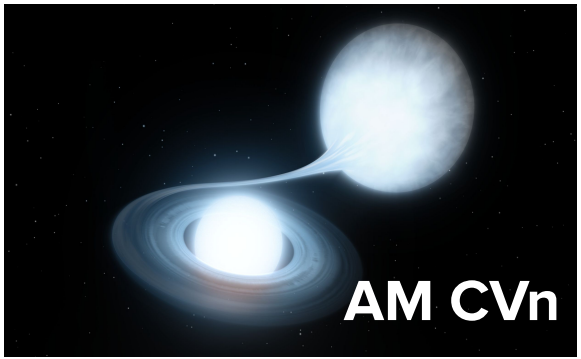
Why they are important for space-based GW astronomy?

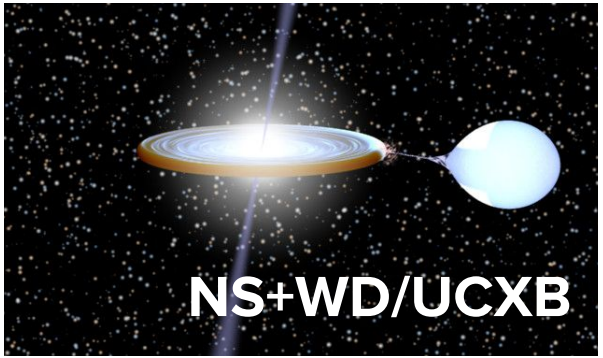
- Guaranteed GW sources
- Can be used to test the instrument performance (e.g. LISA's verification binaries)



Galactic WD+WD/NS binaries



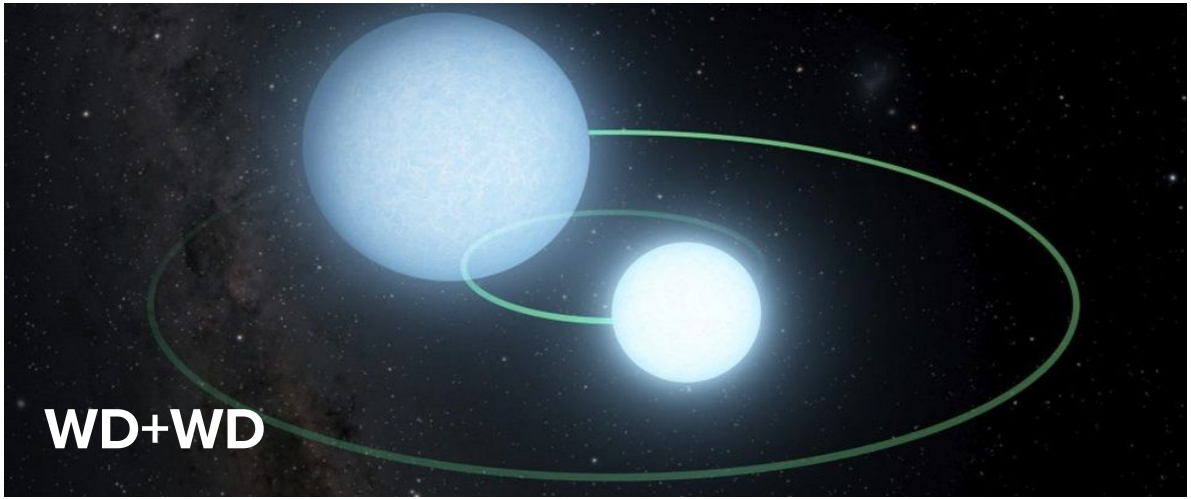


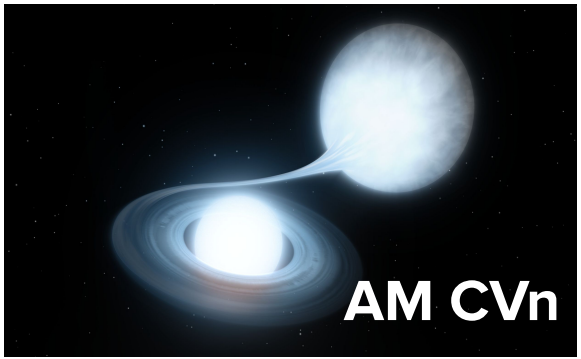


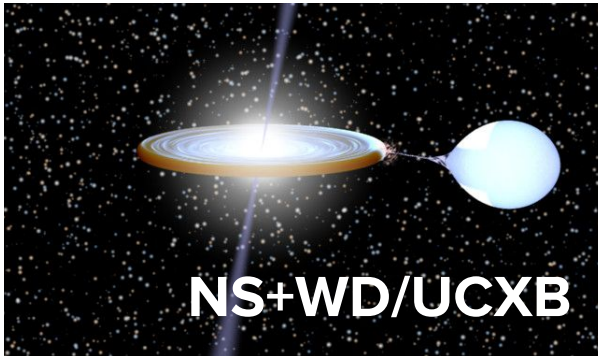
Why they are important for space-based GW astronomy?

- Guaranteed GW sources
- Can be used to test the instrument performance (e.g. LISA's verification binaries)
- Long lifetime makes them abundant at mHz - dHz frequencies

Galactic WD+WD/NS binaries



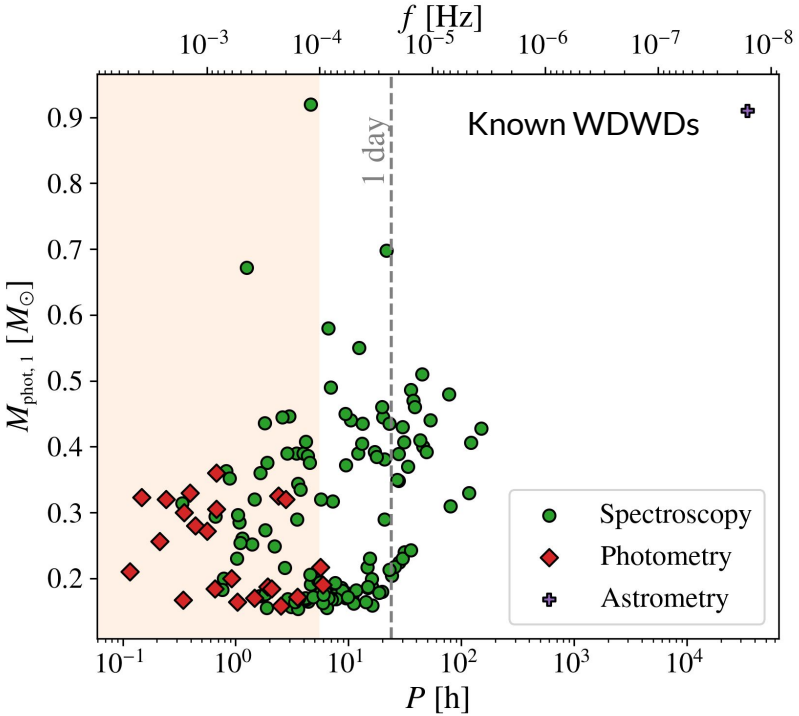




Why they are important for space-based GW astronomy?

- Guaranteed GW sources
- Can be used to test the instrument performance (e.g. LISA's verification binaries)
- Long lifetime makes them abundant at mHz - dHz frequencies
- Guaranteed multi-messenger link with EM transients

What do we know about these binaries from observations?



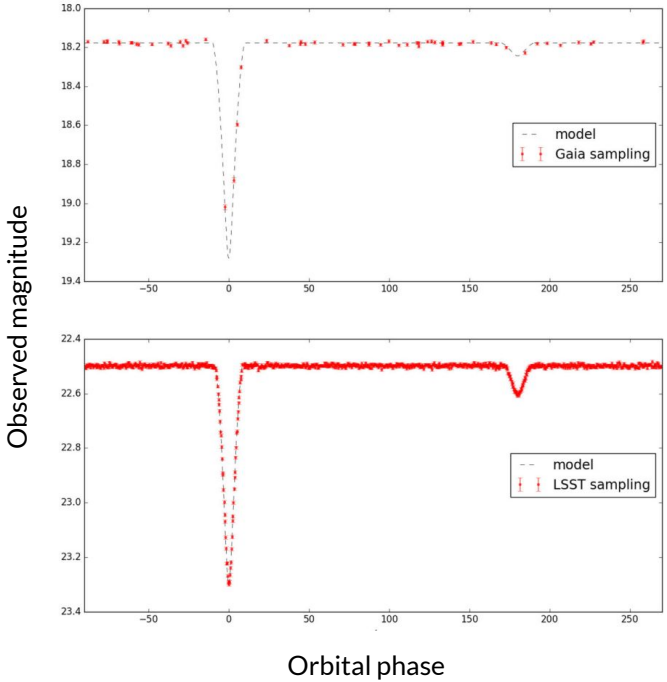
Courtesy of Na'ama Hallakoun

WDWDs: We know of ~150 detached WDWDs in total. Our current knowledge of the population characteristics is poor. The incidence of WDWDs per single WD, their orbital period and component mass distributions are incomplete and biased. Measuring mass of both WD components is especially hard, typically only the brightest is measured .

WDNSs: About 120 are observed as binary radio pulsars in the MW disc, but only about a handful is expected to merge within the Hubble time. There are ~14 UCXBs consisting of NS accreting from a low-mass companion (a WD/a semi-degenerate dwarf/He star); these are mainly found in globular clusters.

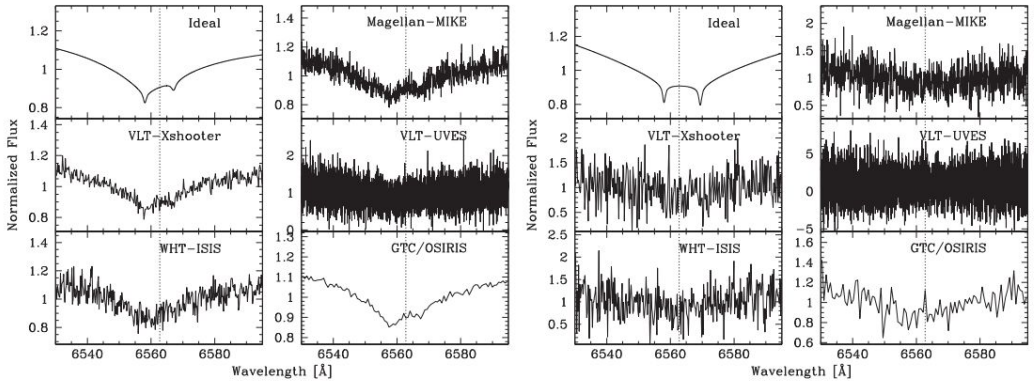
WD+WD/NS are difficult targets for EM telescopes

photometry



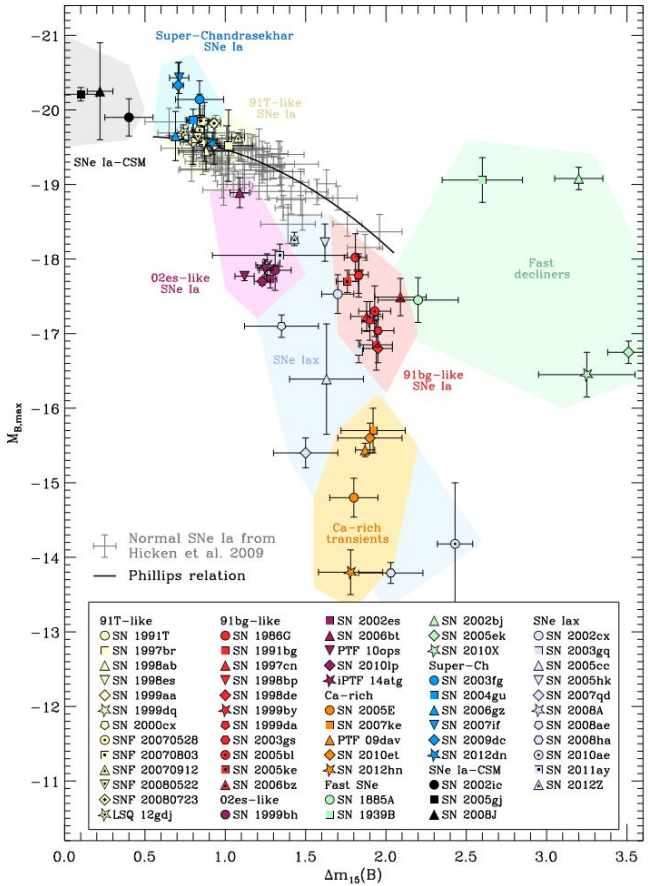
(Korol et al. 2017)

spectroscopy



(Rebassa-Mansergas, Toonen, Korol et al. 2018)

What do we know about these binaries from observations?



Taubenberger 2017

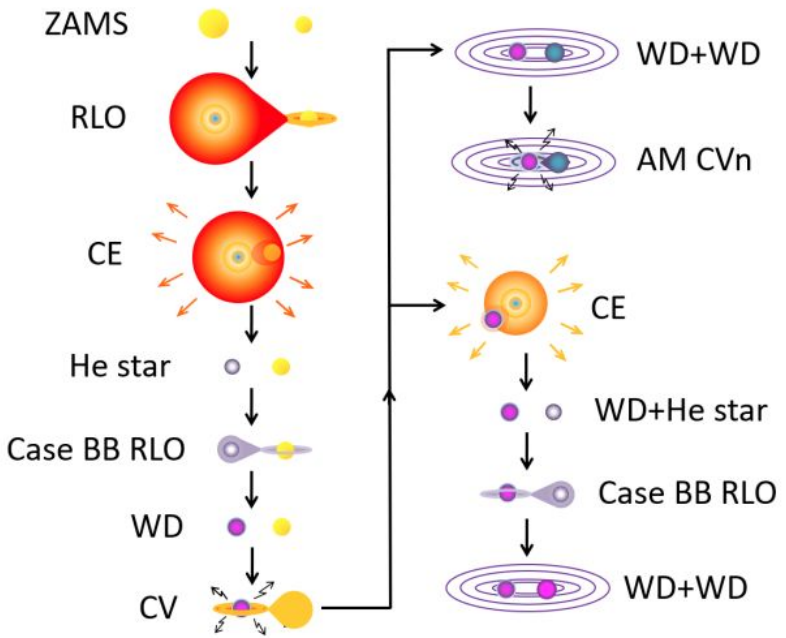
Explosions of carbon-oxygen WD in binary systems (either due to reaching the Chandrasekhar limit via accretion or via merger) lead to Type Ia supernovae (SNe Ia).

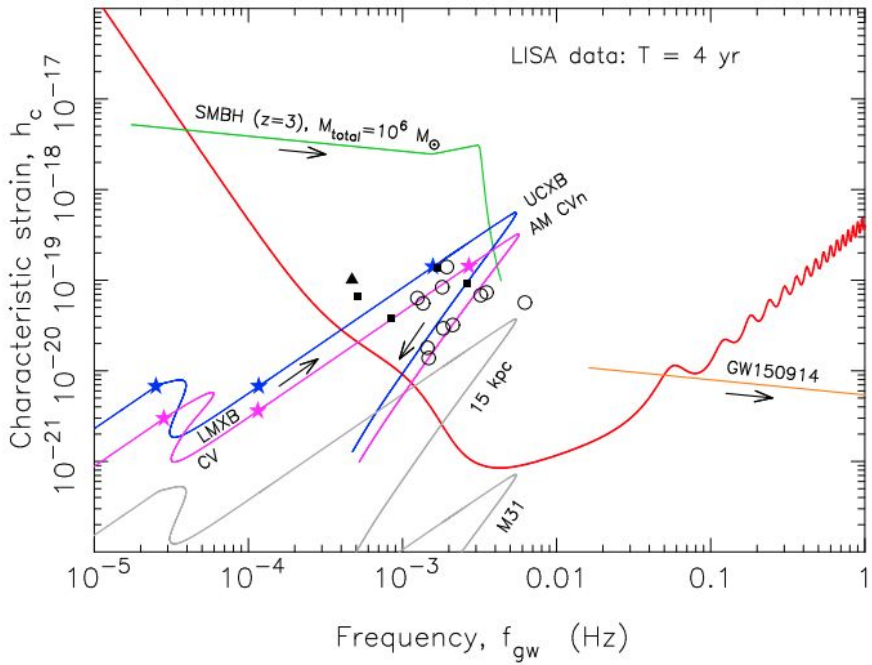
A number of transient classes deviating from the luminosity relationship of 'normal' SNe Ia have been discovered over the past couple decades.

The connection of these observed transients to progenitor systems is unclear. Not all of them are necessarily thermonuclear explosions, but there are good arguments in favour of a thermonuclear origin for most of them.

What do we know about these binaries from theory?

A typical formation scenario requires at least two episodes of mass transfer, one of which should be a common envelope.

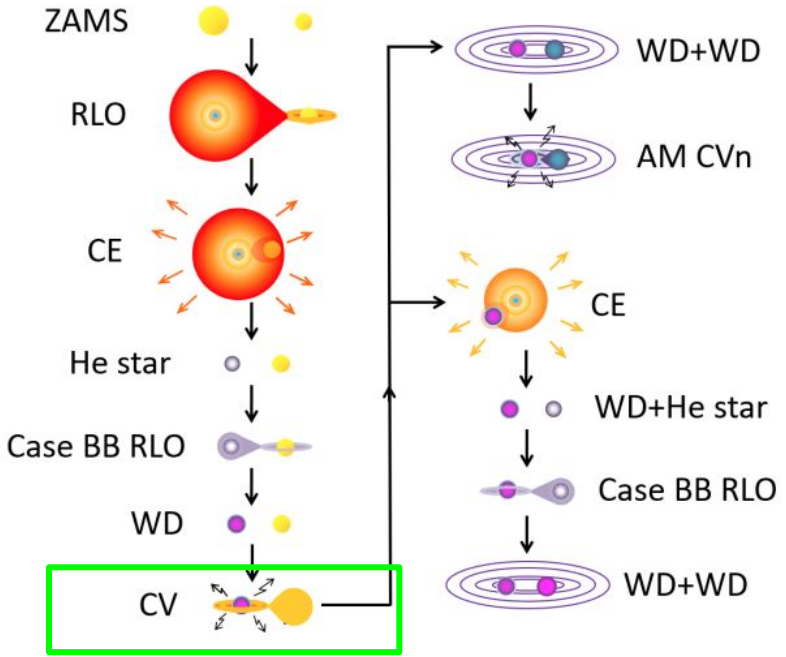


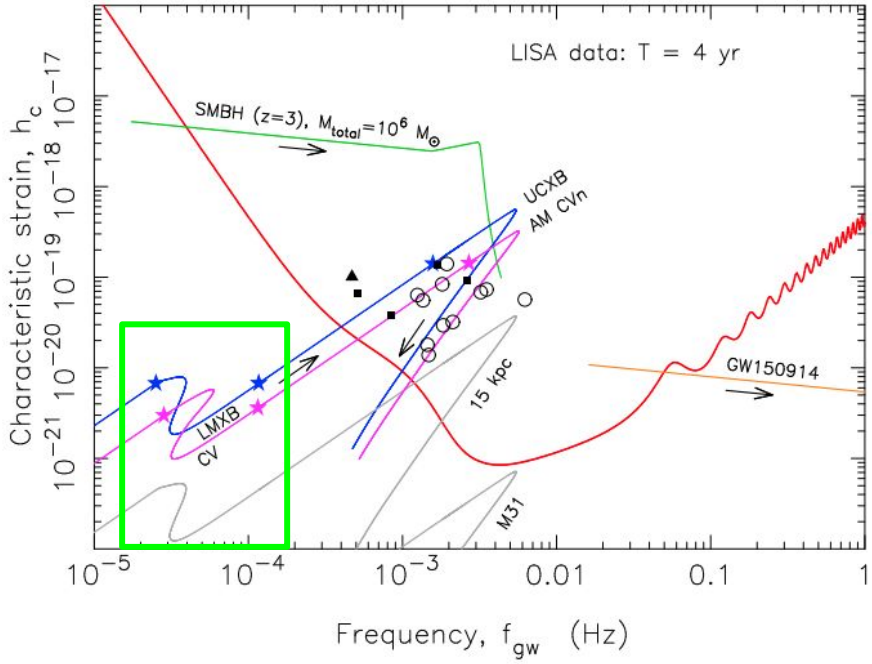


Tauris and van den Heuvel (2022), Amaro-Seoane et al. (2023)

What do we know about these binaries from theory?

A typical formation scenario requires at least two episodes of mass transfer, one of which should be a common envelope.

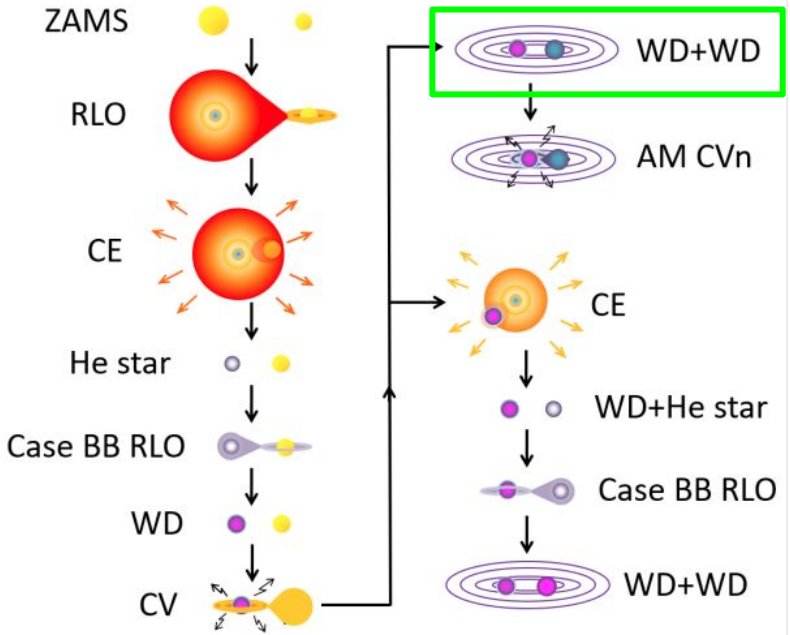


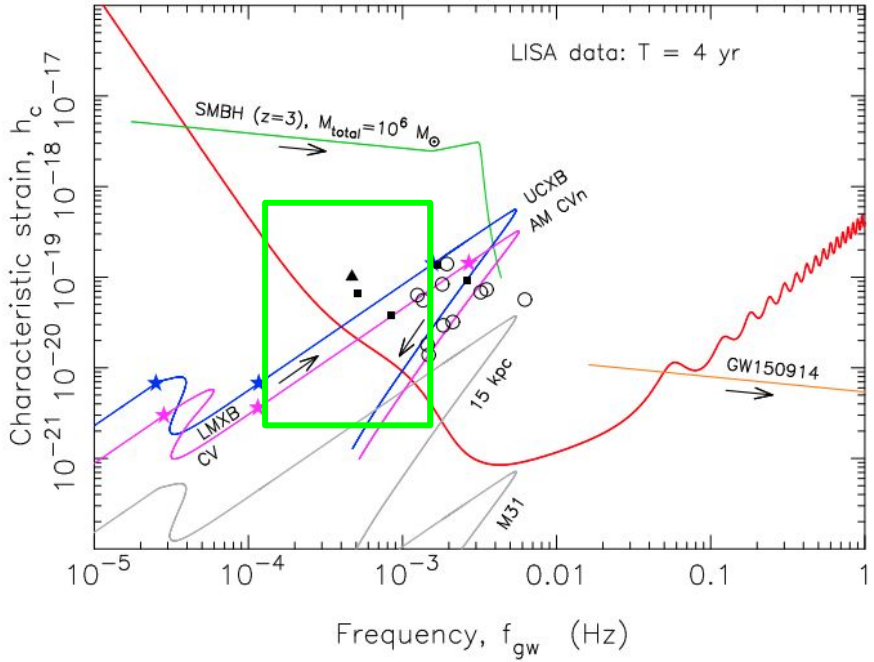


Tauris and van den Heuvel (2022), Amaro-Seoane et al. (2023)

What do we know about these binaries from theory?

A typical formation scenario requires at least two episodes of mass transfer, one of which should be a common envelope.

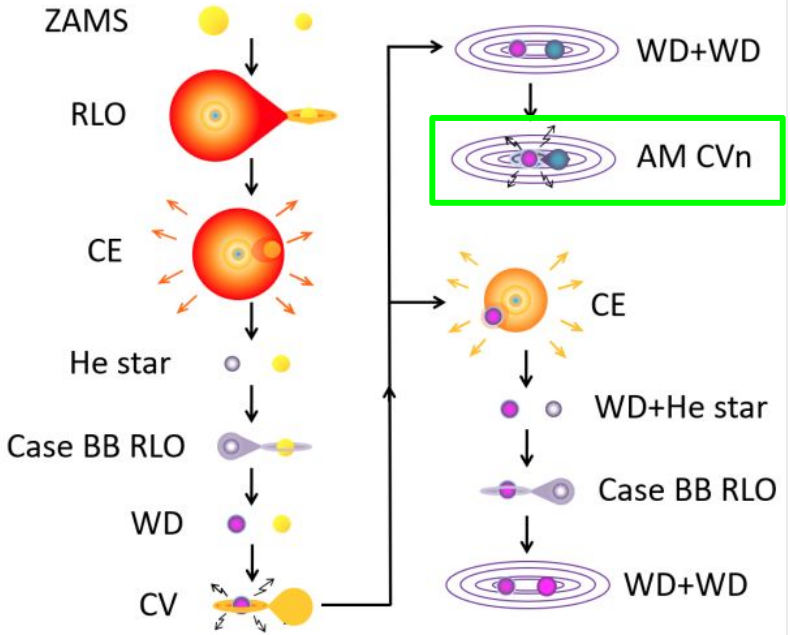


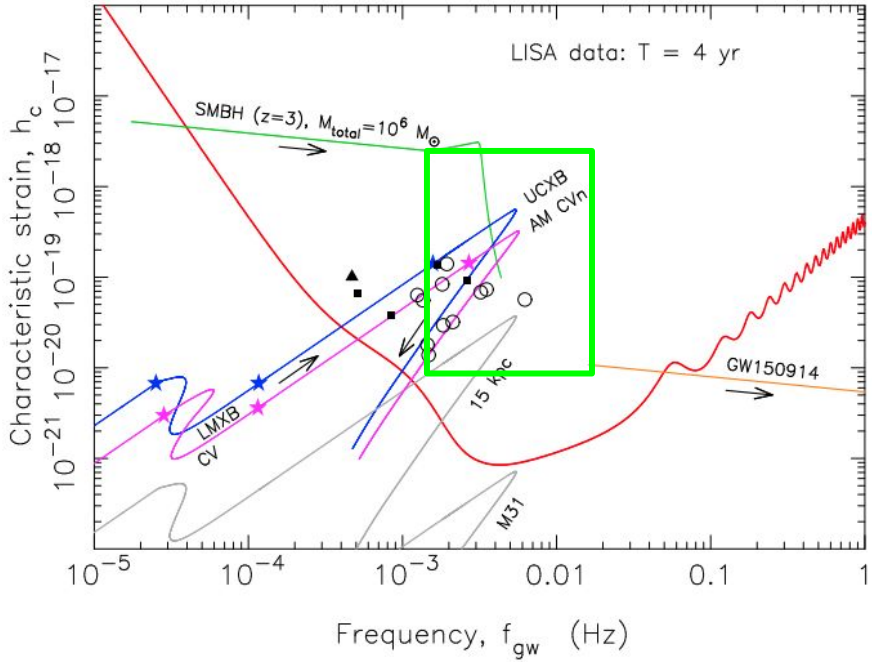


Tauris and van den Heuvel (2022), Amaro-Seoane et al. (2023)

What do we know about these binaries from theory?

A typical formation scenario requires at least two episodes of mass transfer, one of which should be a common envelope.

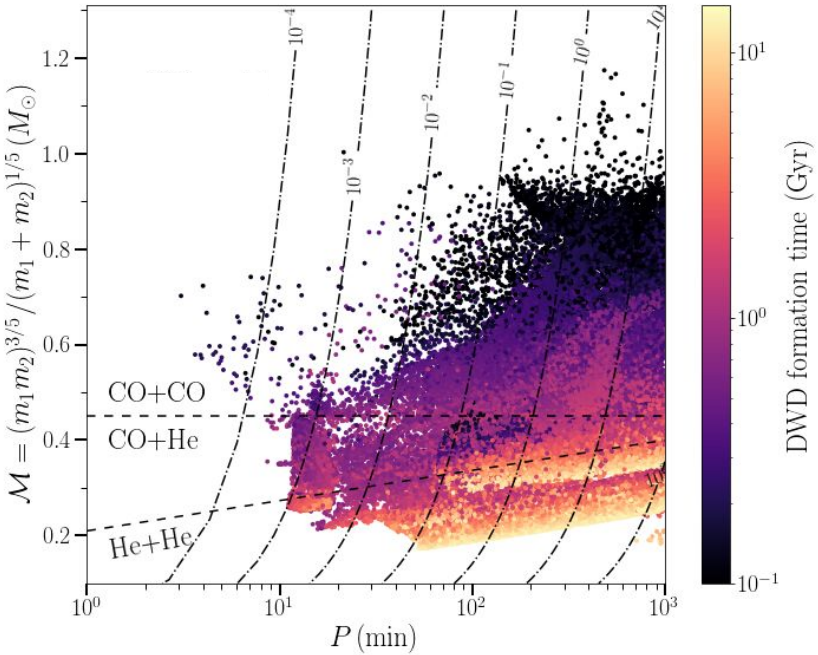




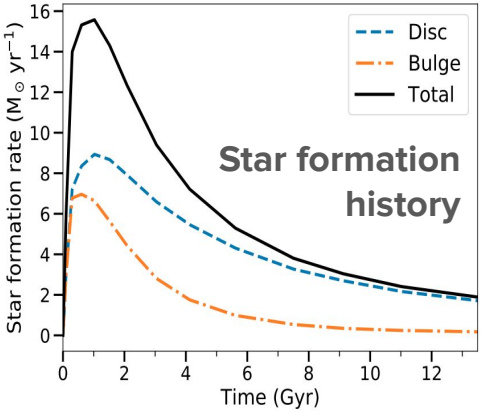
Tauris and van den Heuvel (2022), Amaro-Seoane et al. (2023)

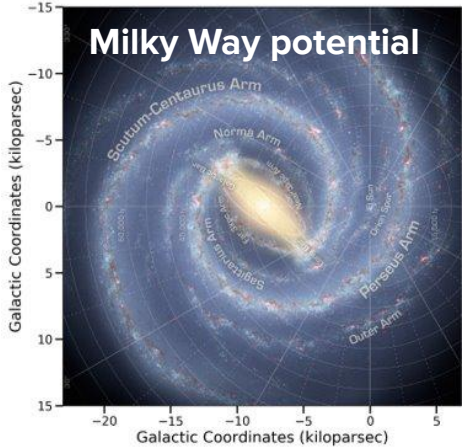
Forecasting WD+WD/NS population

When forecasting GW observations, we mainly rely on the **binary population synthesis** (BPS) technique.

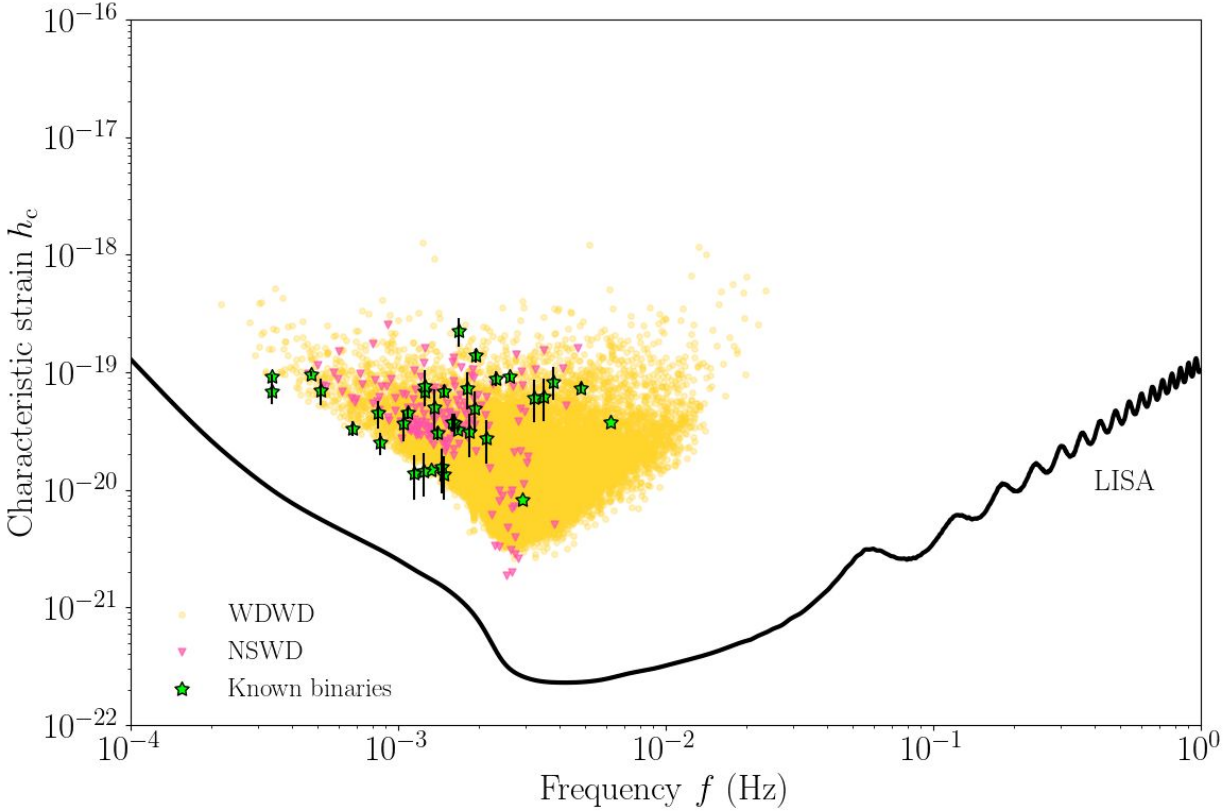


Toonen et al. 2012, 2017, 2018, based on SeBa BPS code
See also: Nelemans et al. (2001), Ruiter et al. (2010), Yu & Jaffery (2010), Lamberts et al. (2018), Breivik et al. (2020), Li et al. (2020) and others



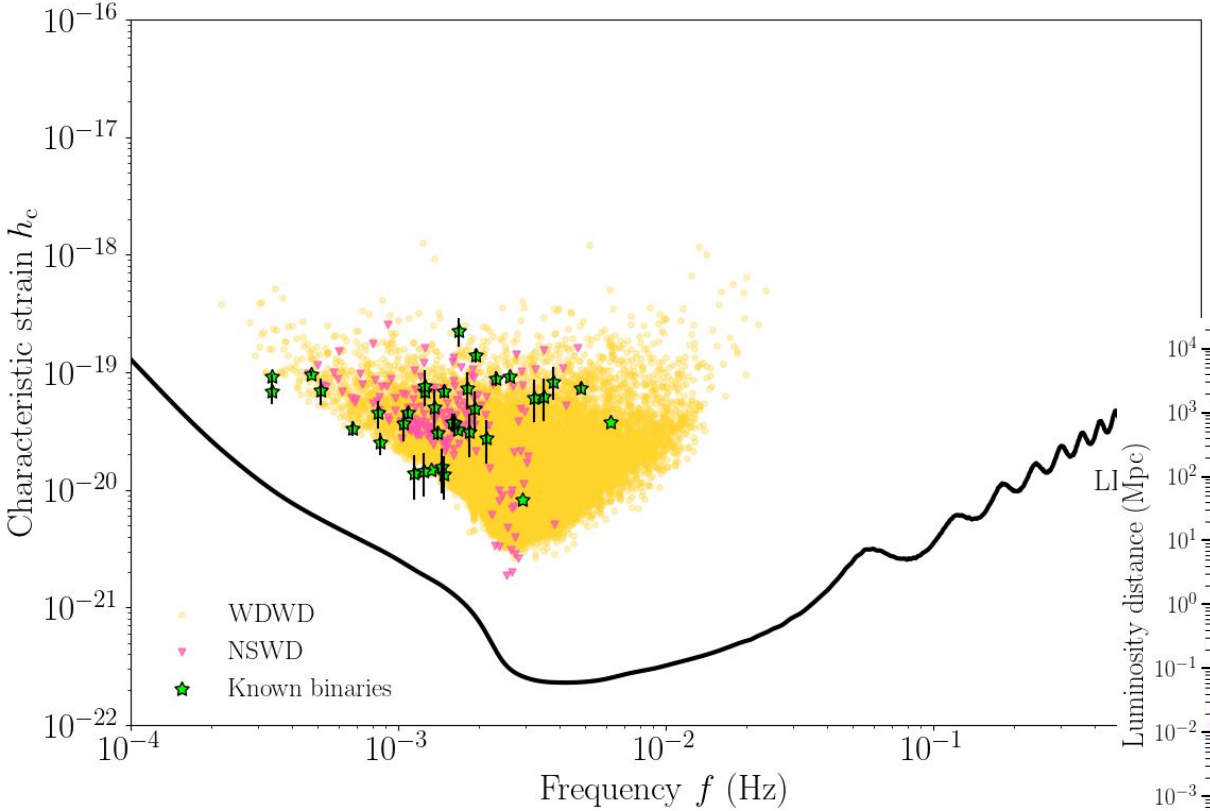


Forecasting WD+WD/NS population



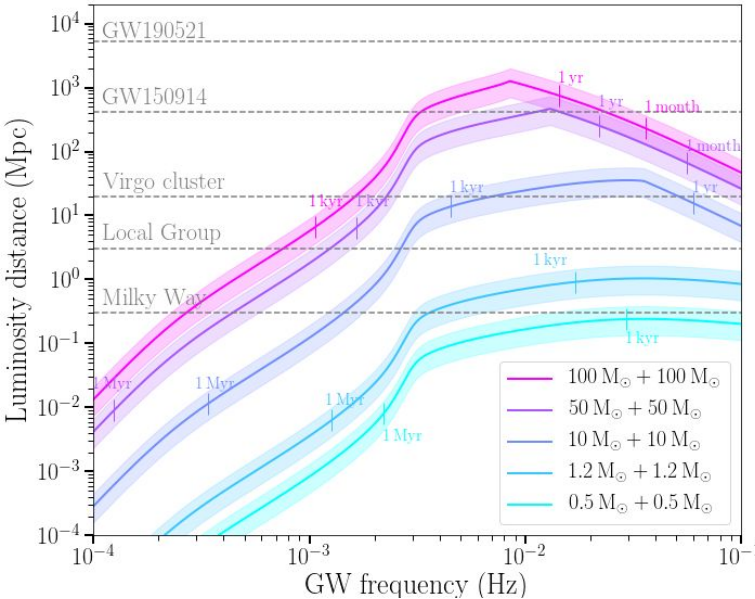
LISA will deliver $\mathcal{O}(10^4)$ WDWD and $\mathcal{O}(10^2)$ WDNS of individual (resolved) GW signals and an unresolved Galactic foreground (LISA Astrophysics white paper 2023).

Forecasting WD+WD/NS population

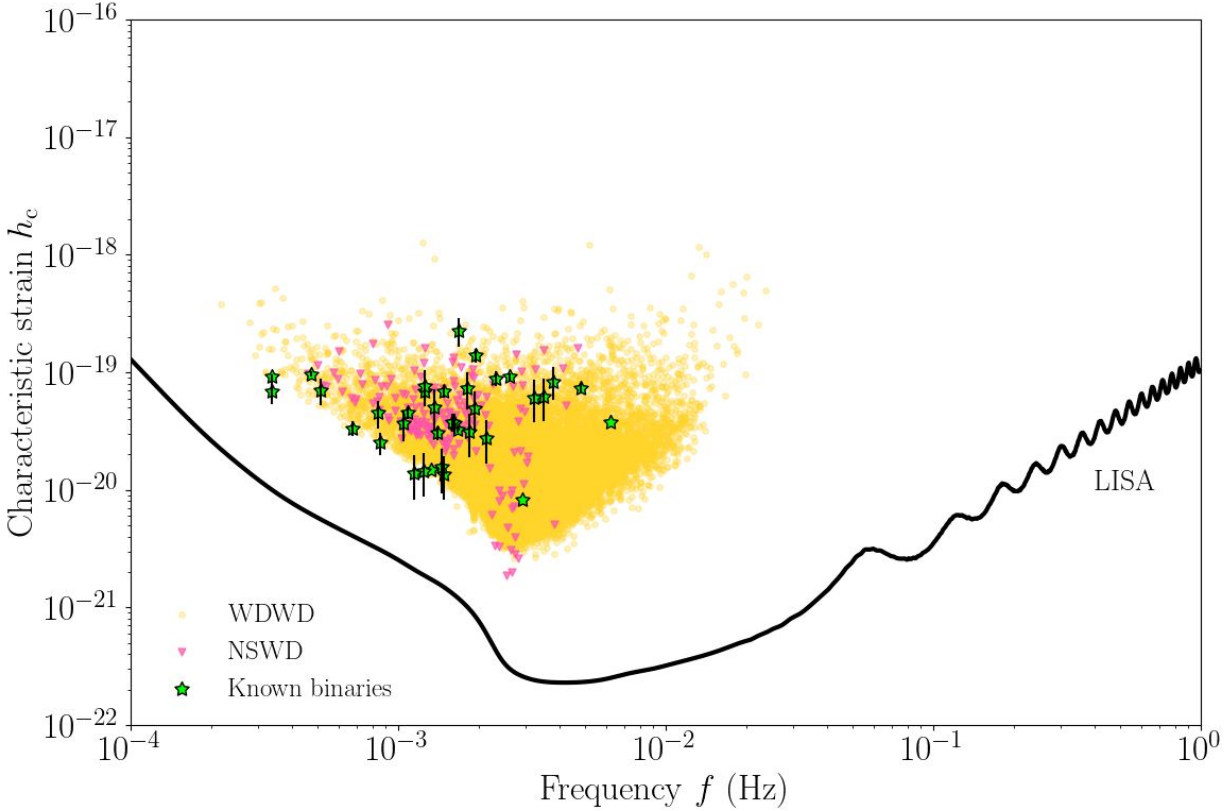


LISA will deliver $\mathcal{O}(10^4)$ WDWD and $\mathcal{O}(10^2)$ WDNS of individual (resolved) GW signals and an unresolved Galactic foreground (LISA Astrophysics white paper 2023).

LISA's will access these binaries up to 100s of kpc as far as the Andromeda galaxy for the most massive ones.



Forecasting WD+WD/NS population

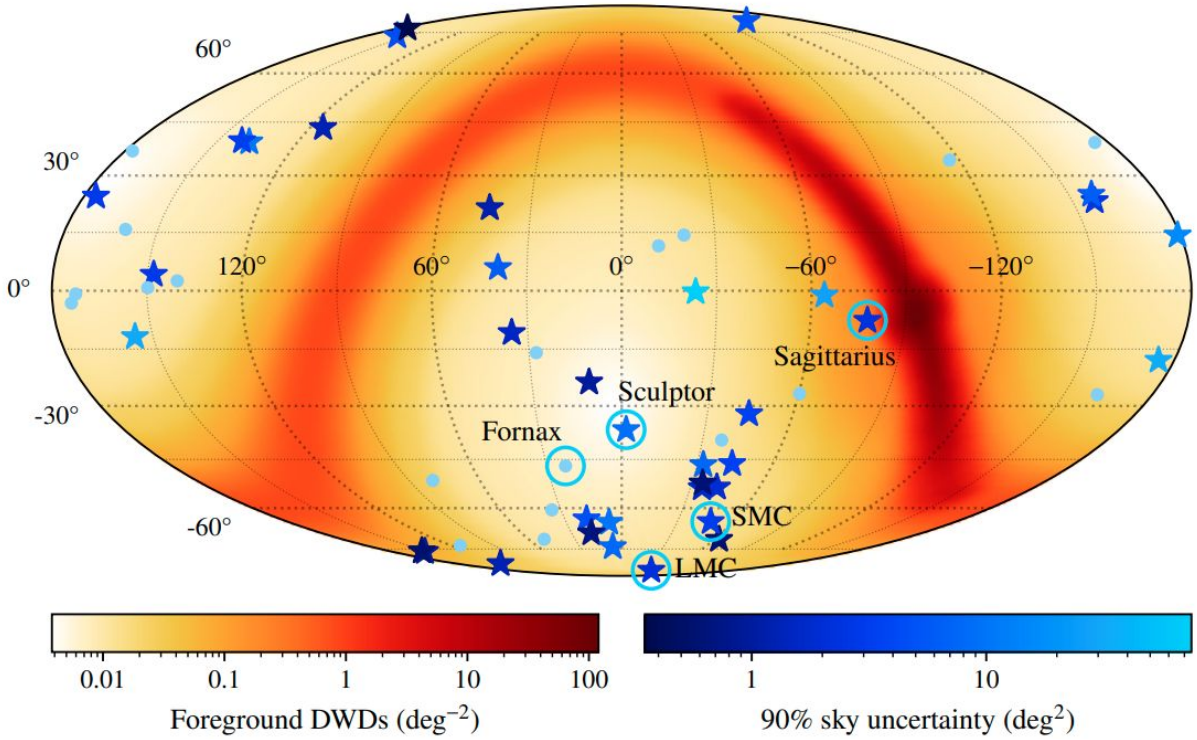


LISA will deliver $\mathcal{O}(10^4)$ WDWD and $\mathcal{O}(10^2)$ WDNS of individual (resolved) GW signals and an unresolved Galactic foreground (LISA Astrophysics white paper 2023).

LISA's will access these binaries up to 100s of kpc as far as the Andromeda galaxy for the most massive ones.

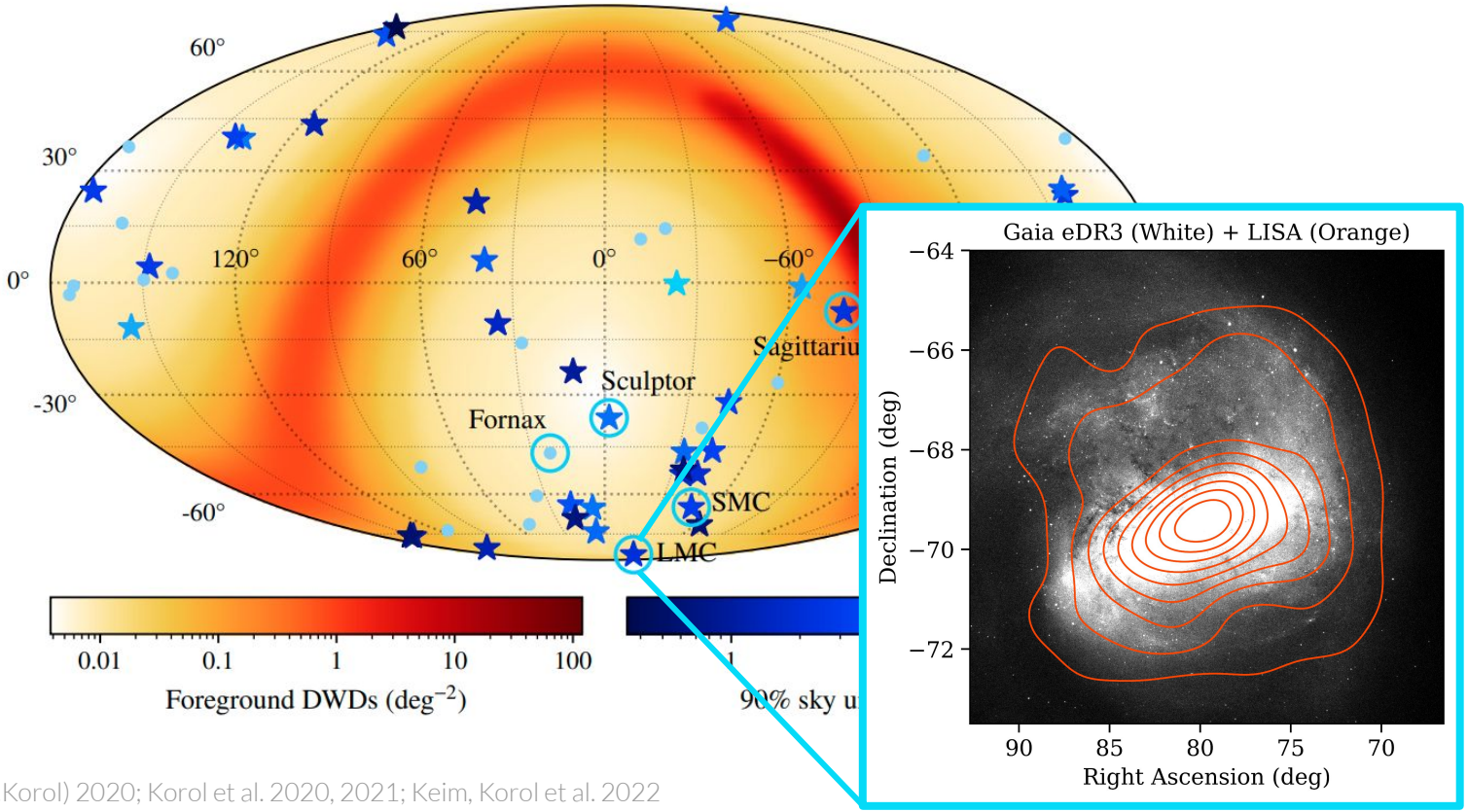
LISA's sample will be complete down to orbital periods of 20 min within the Milky Way and the Magellanic Clouds.

(Re-)discovering Milky Way satellites in gravitational waves



Roebber et al. (incl.Korol) 2020; Korol et al. 2020, 2021; Keim, Korol et al. 2022

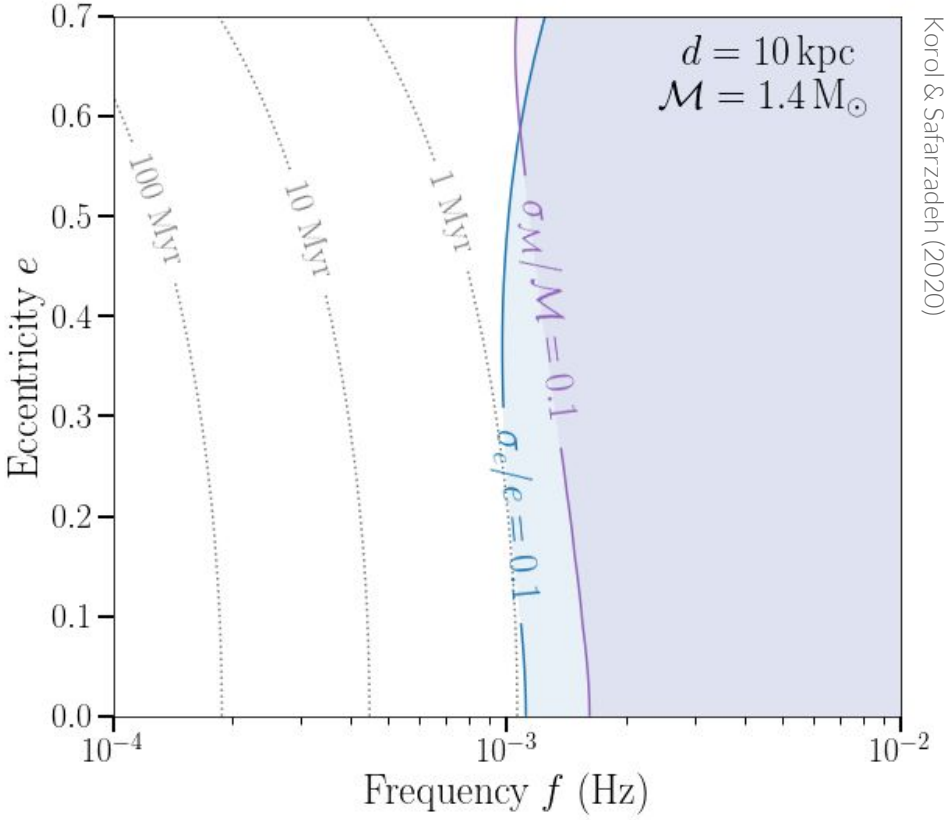
(Re-)discovering Milky Way satellites in gravitational waves



Roebber et al. (incl.Korol) 2020; Korol et al. 2020, 2021; Keim, Korol et al. 2022

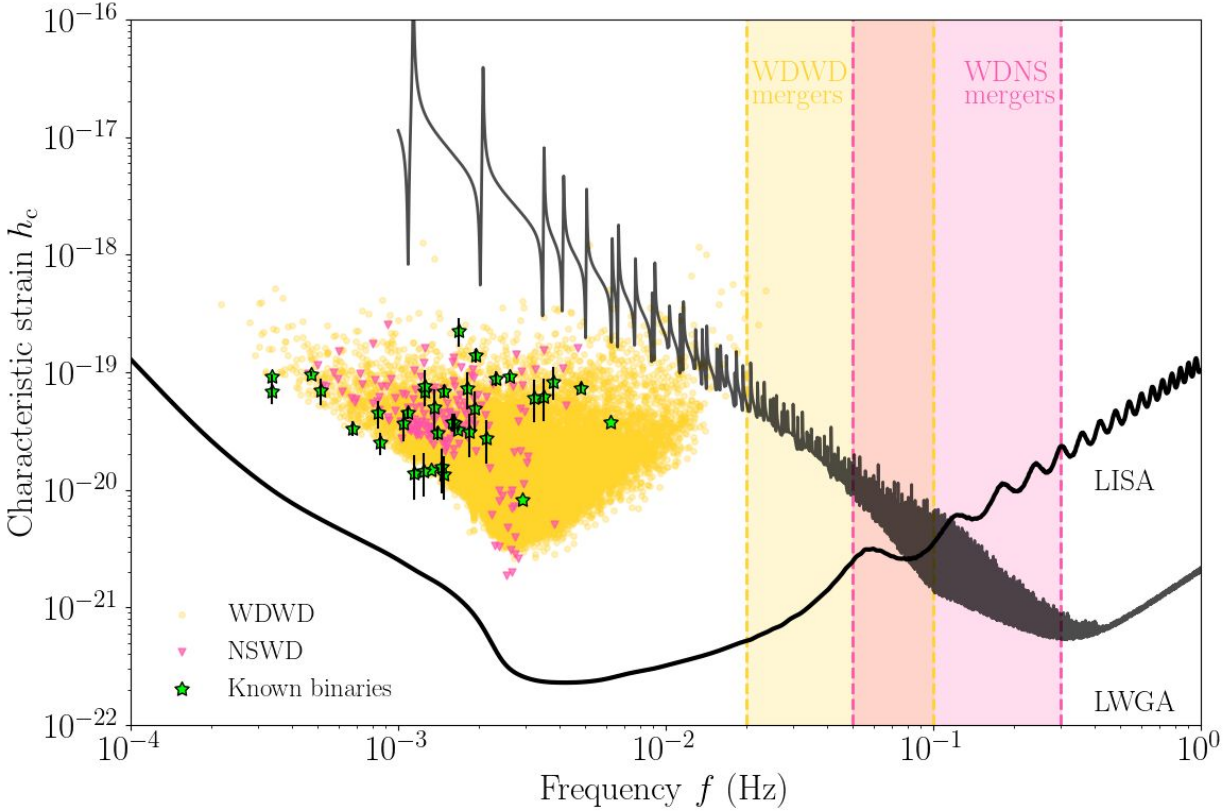
What binary parameters will LISA measure?

- Frequency $\sigma f/f << 10^{-6}$
- Frequency derivative for binaries at $f \gtrsim 2$ mHz
- Eccentricity for binaries at $f \gtrsim 2$ mHz
- Chirp mass and luminosity distance for binaries for binaries with measured frequency derivative and eccentricity
- Sky location $\Delta\Omega \sim \mathrm{deg}^2$



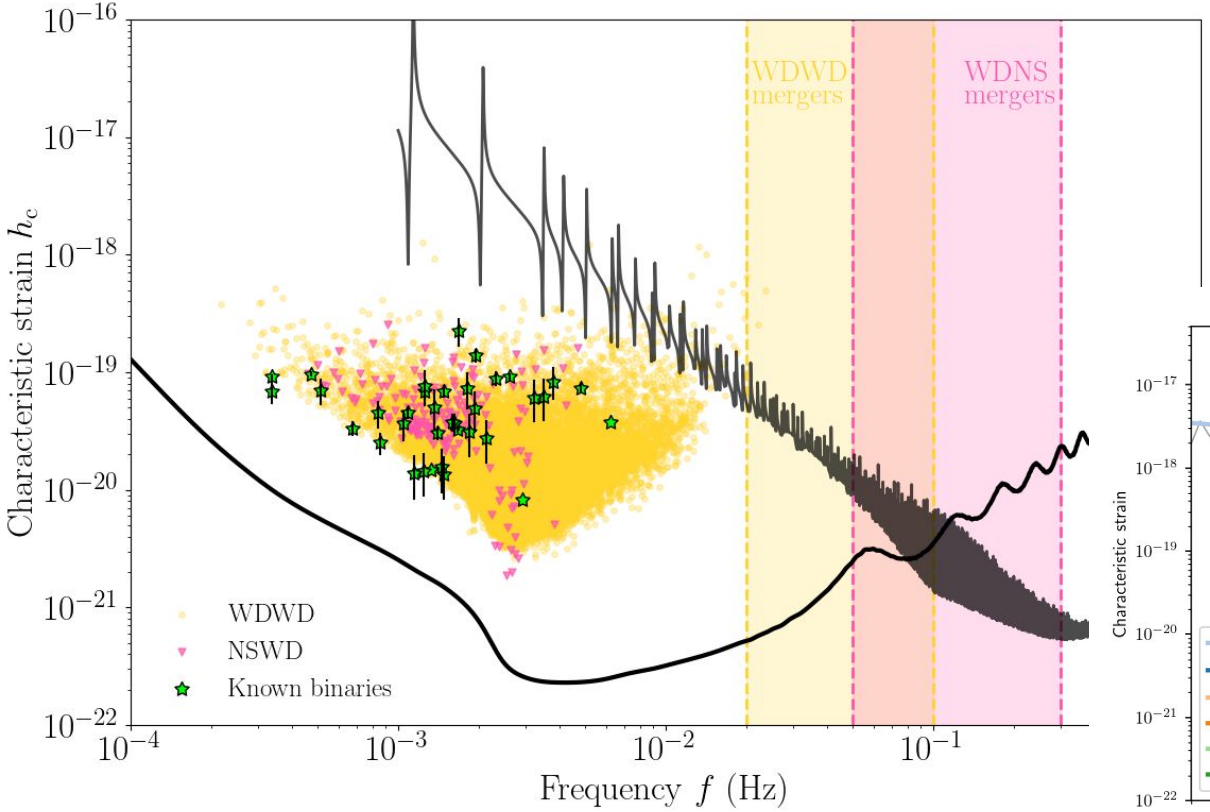
Korol & Safarzadeh (2020)

From LISA to LGWA

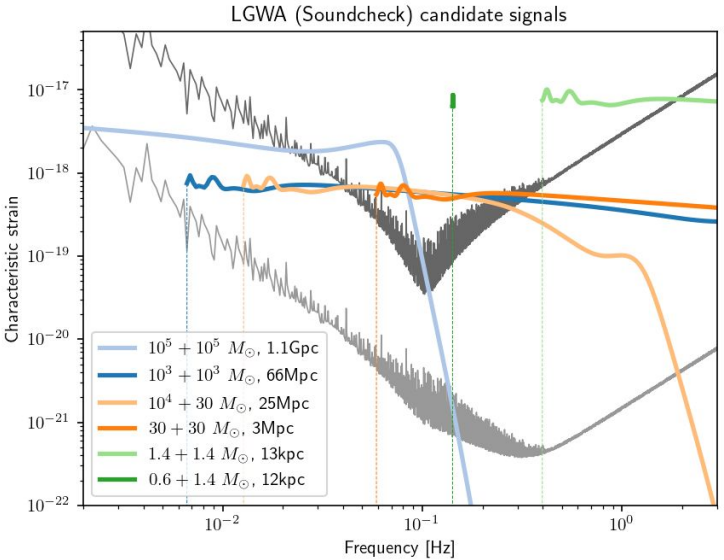


- Is the LGWA WD/NS science driven by continues or transient (i.e. mergers) signals?

From LISA to LGWA

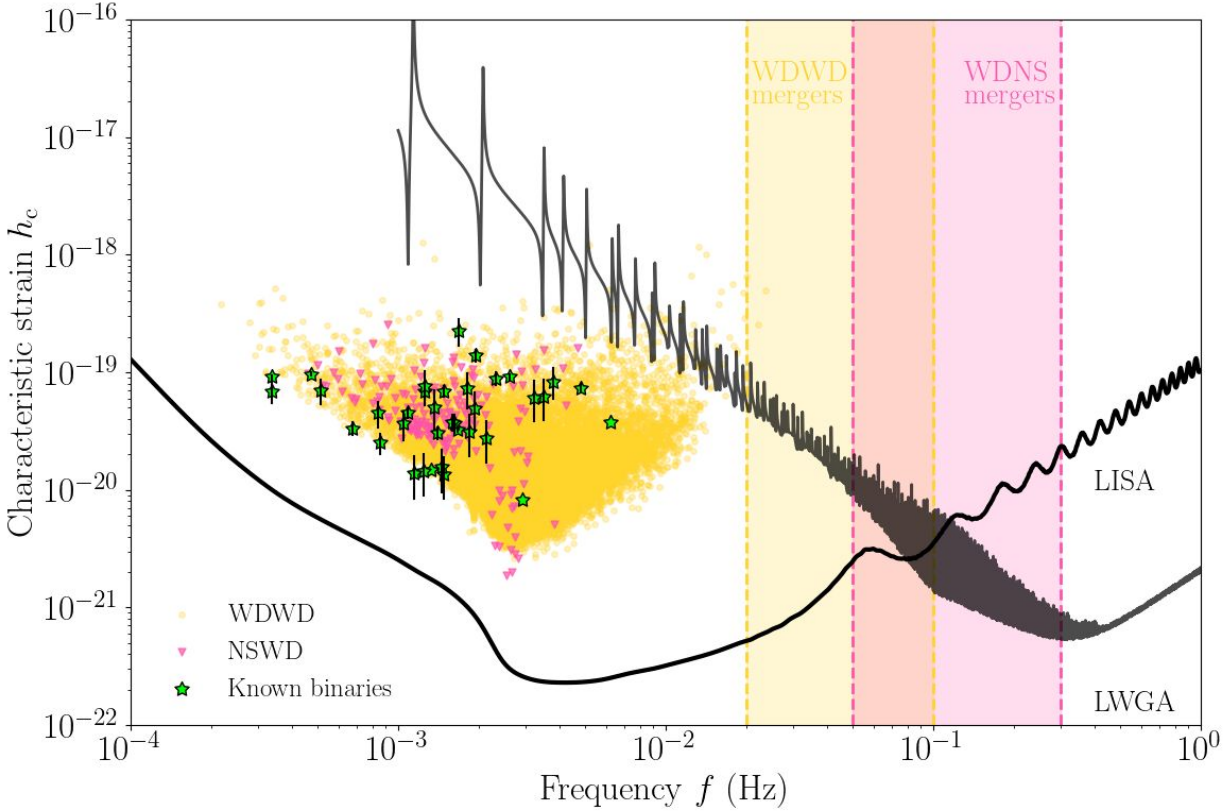


- Is the LGWA WD/NS science be driven by continues or transient (i.e. mergers) signals?
- How far WD/NS binaries and their mergers can be detected?



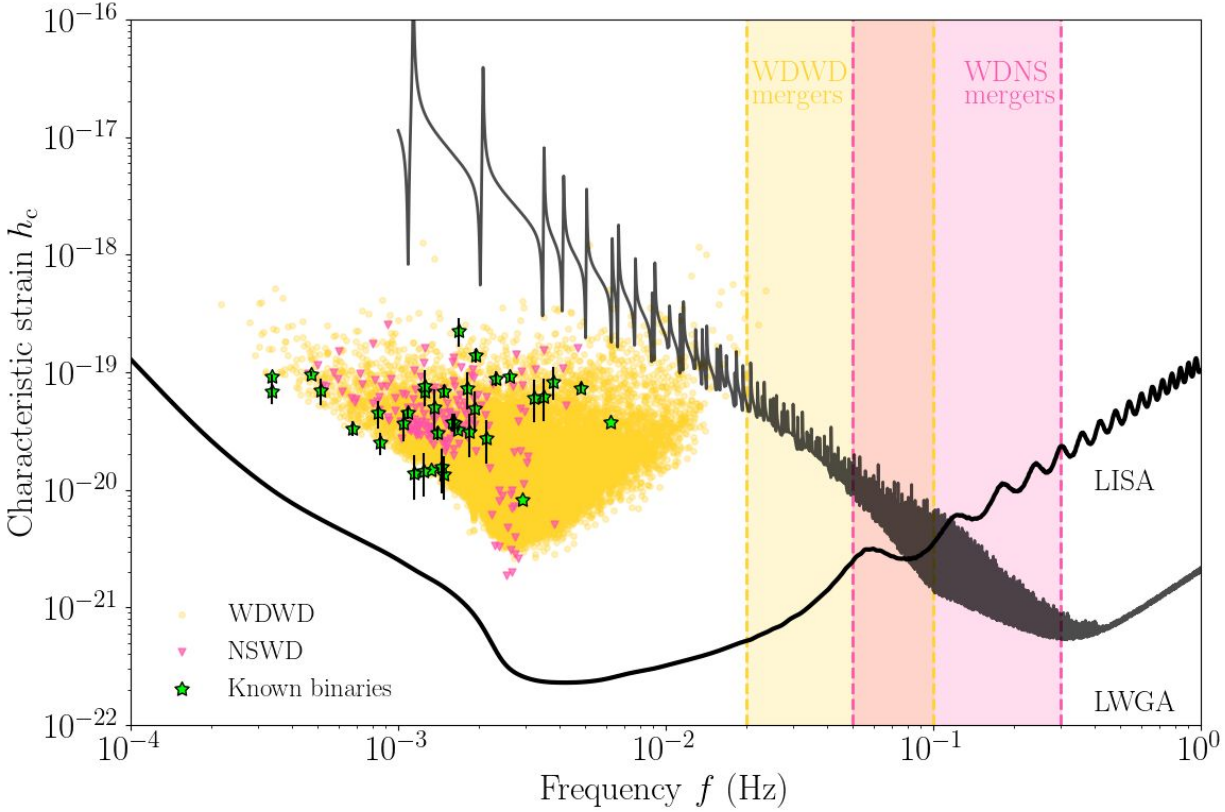
http://lgwa.unicam.it/

From LISA to LGWA



- Is the LGWA WD/NS science be driven by continues or transient (i.e. mergers) signals?
- How far WD/NS binaries and their mergers can be detected?
- How many binaries/mergers LGWA has potential to detect?

From LISA to LGWA

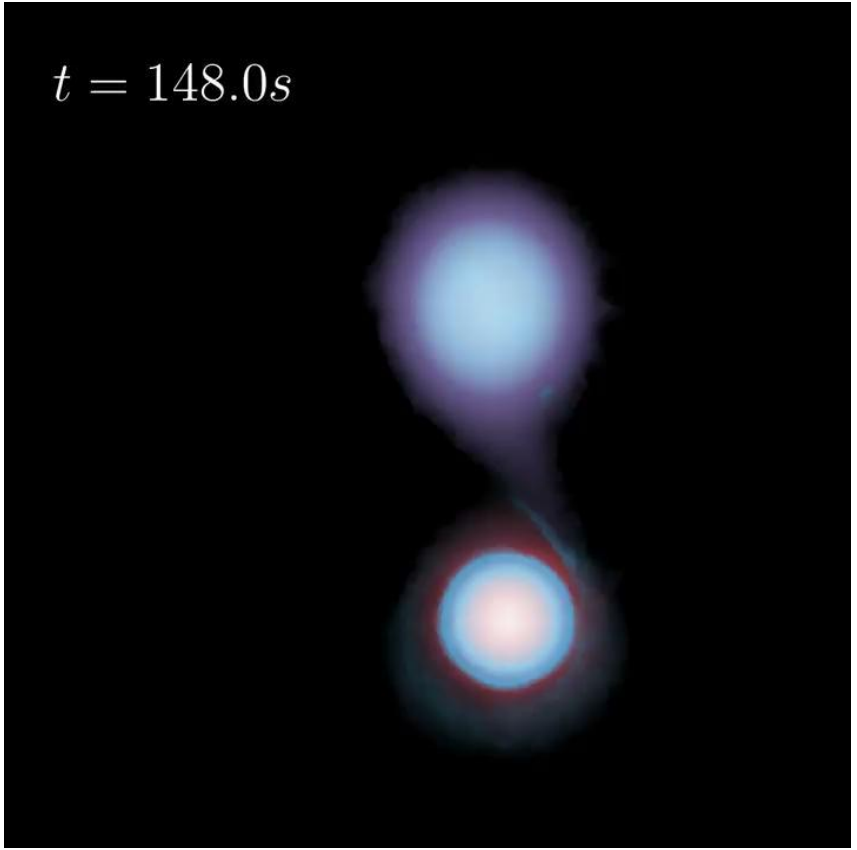


- Is the LGWA WD/NS science be driven by continues or transient (i.e. mergers) signals?
- How far WD/NS binaries and their mergers can be detected?
- How many binaries/mergers LGWA has the potential to detect?
- What are the multi-band synergies with LISA? (e.g. GWfish study for IMBHs by Dupletsa et al. 2023)
- What are multi-messenger opportunities can be exploited?

The luckiest case: observing the merger event followed by an electromagnetic counterpart

Although the chances of observing a local SN Ia-like explosion are low, a multi-messenger detection would be the most direct way of linking the progenitor to the explosion.

In addition, from the GW signal during the merger we could learn details that are hard/impossible with electromagnetic observations alone.



Pakmor et al. 2022