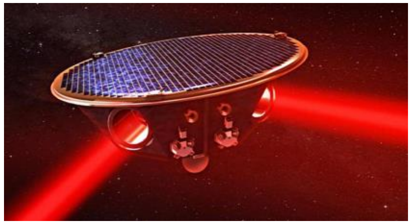
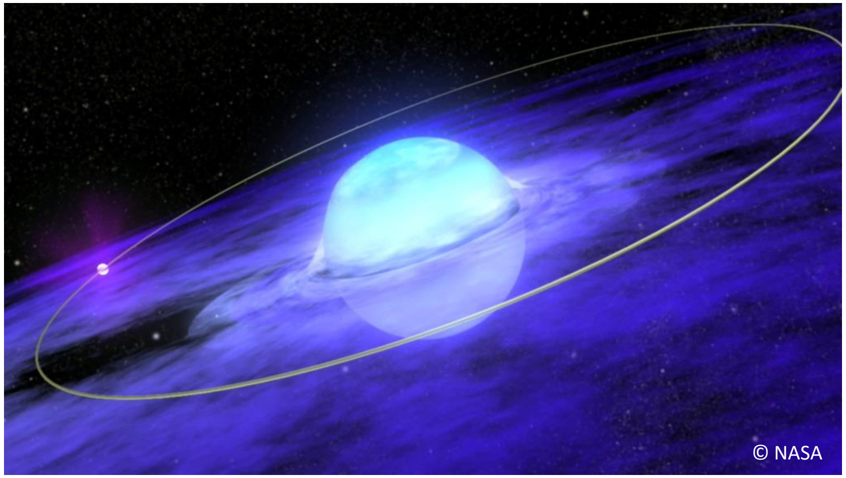
THOMAS TAURIS
HAI-LIANG CHEN





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Investigating Coalescing NS-WD Binaries for LISA

Mar. 10, 2020 Nijmegen / ZOOM

AARHUS UNIVERSITY

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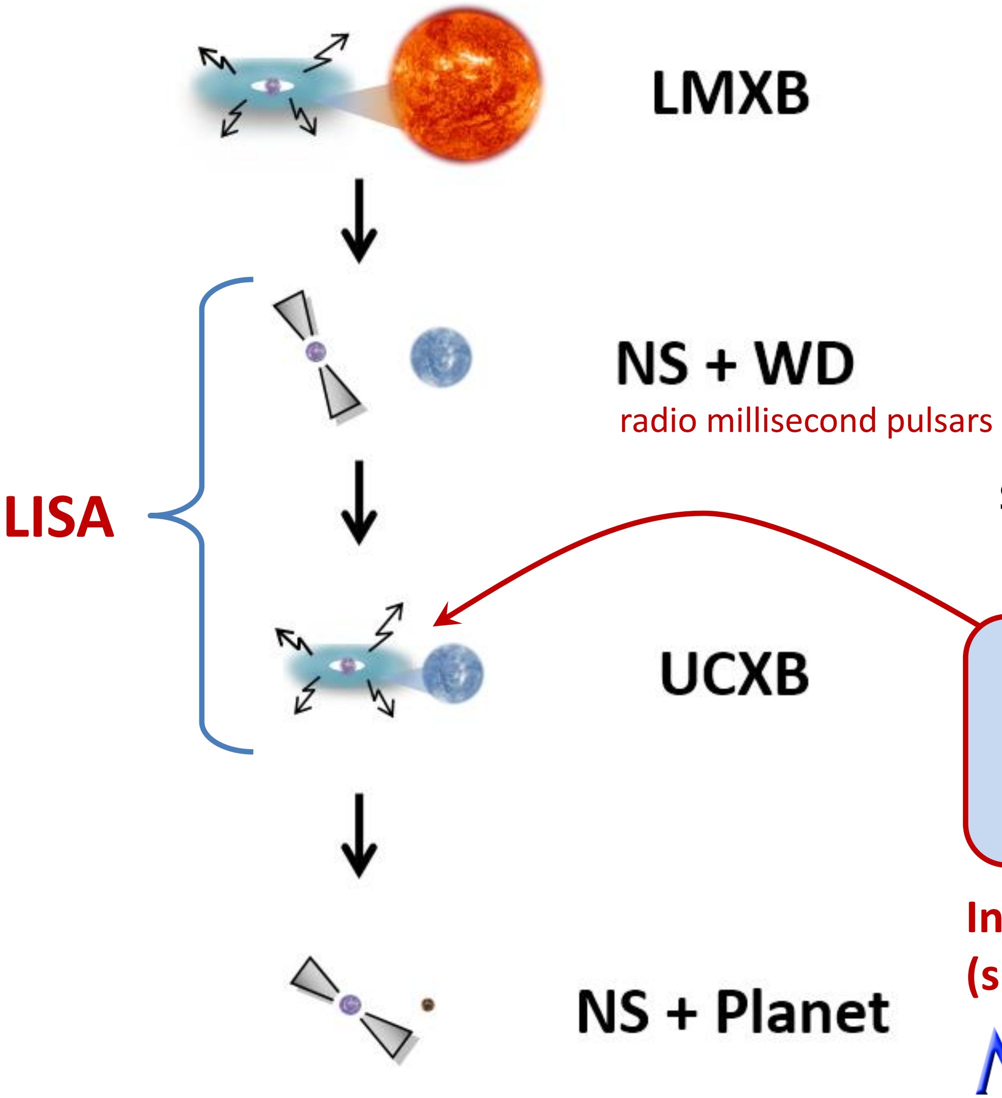
ADVANCED STUDIES

INSTITUT FOR FYSIK OG ASTRONOMI
IFA

中国科学院云南天文台
YUNNAN OBSERVATORIES, CAS

SELF-CONSISTENT NUMERICAL CALCULATIONS



LMXB

LISA

NS + WD

radio millisecond pulsars

UCXB

NS + Planet

Rahul Sengar

Alina Istrate

Sengar, Tauris, Langer & Istrate (2017)
MNRAS Letters 470, L6

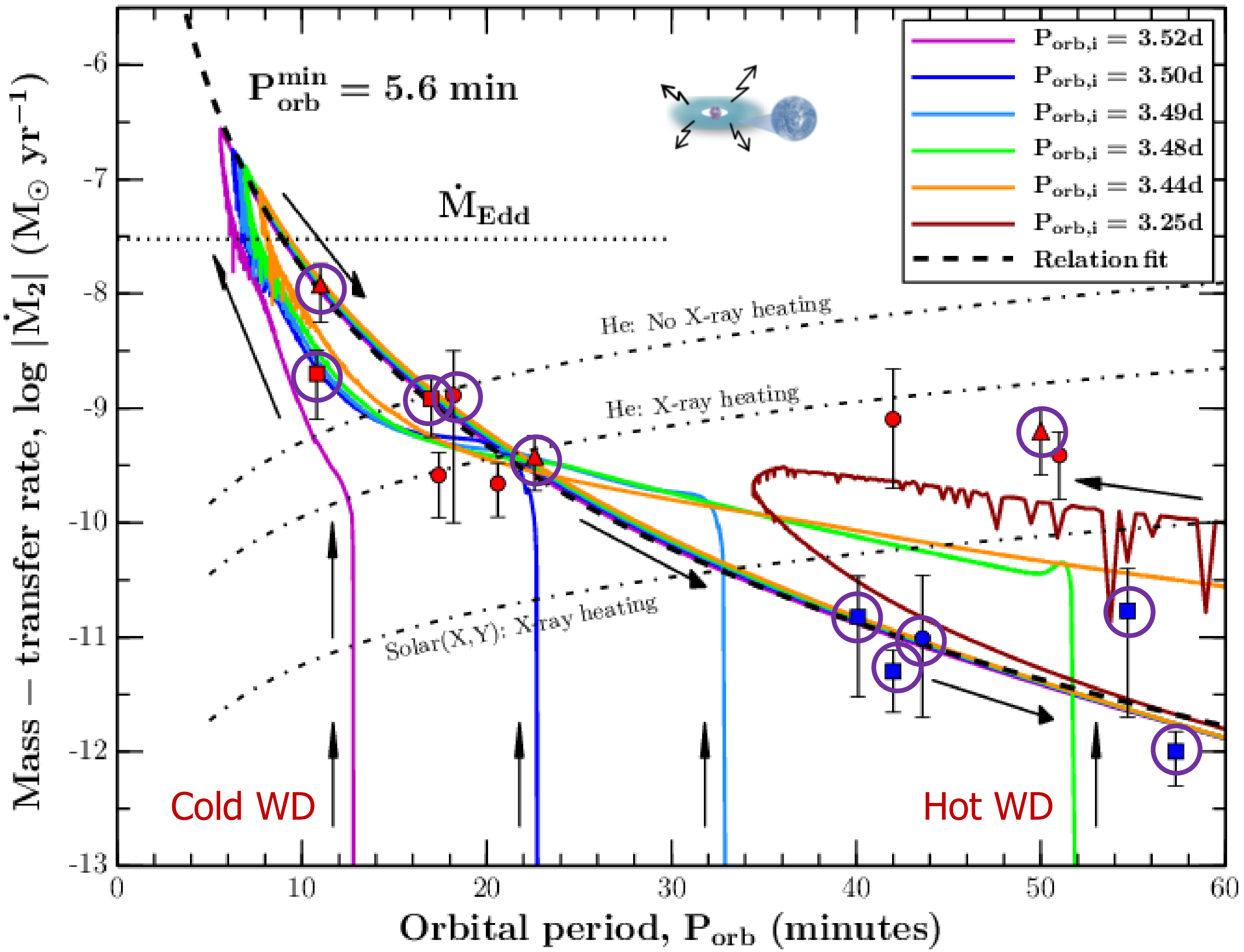
First calculations of stable mass transfer from a WD to a NS

Includes finite-temperature effects (specific entropy) of the WD donor

MESA

FIRST NUMERICAL CALCULATIONS OF UCXBs

Sengar et al. (2017)



Obs. data from
Heinke et al. (2013)

■ ?

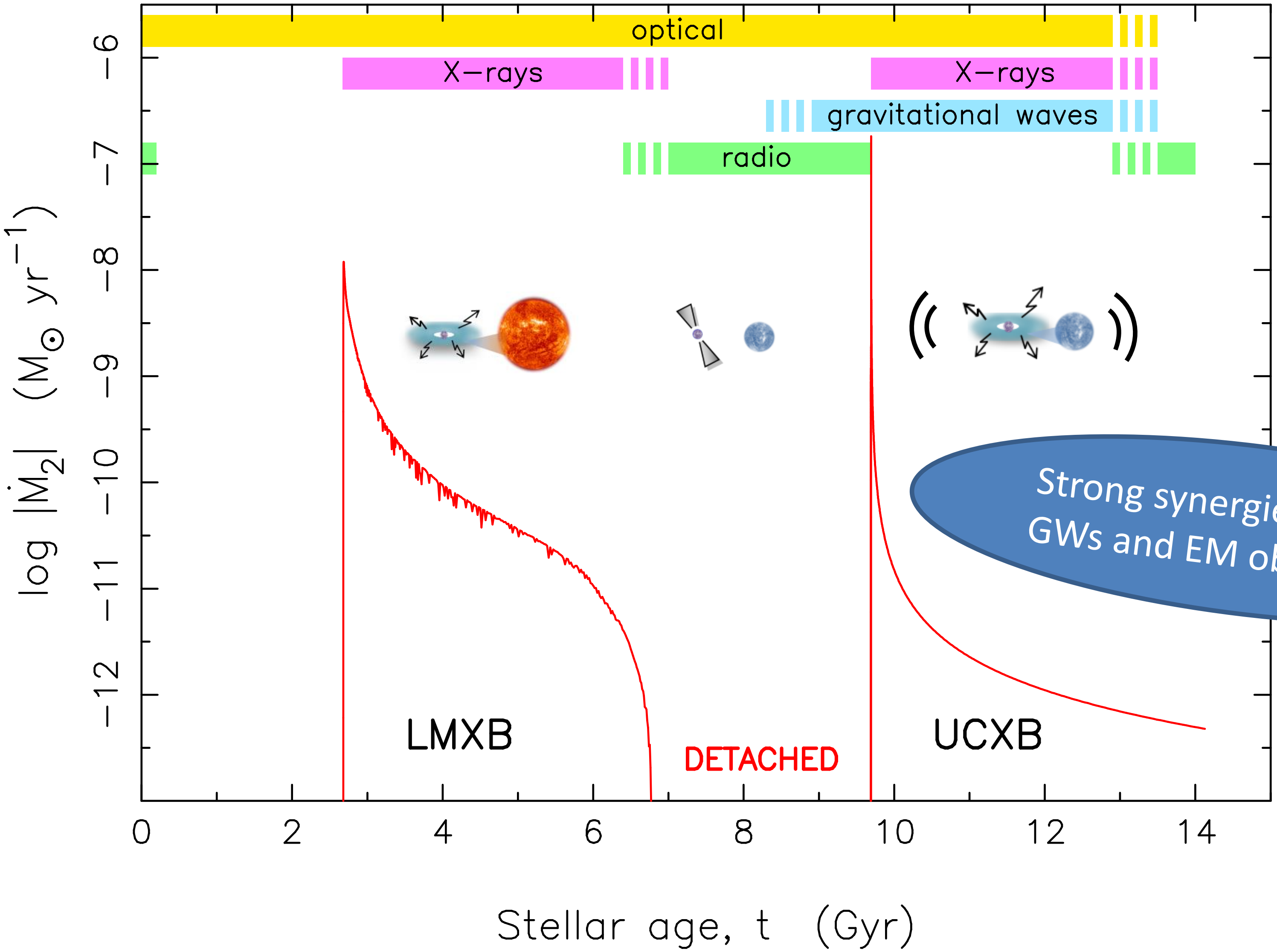
▲ He

● no He

🟥 persistent

🟦 transient

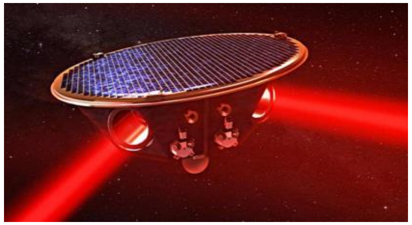
MULTI-MESENGER ASTRONOMY

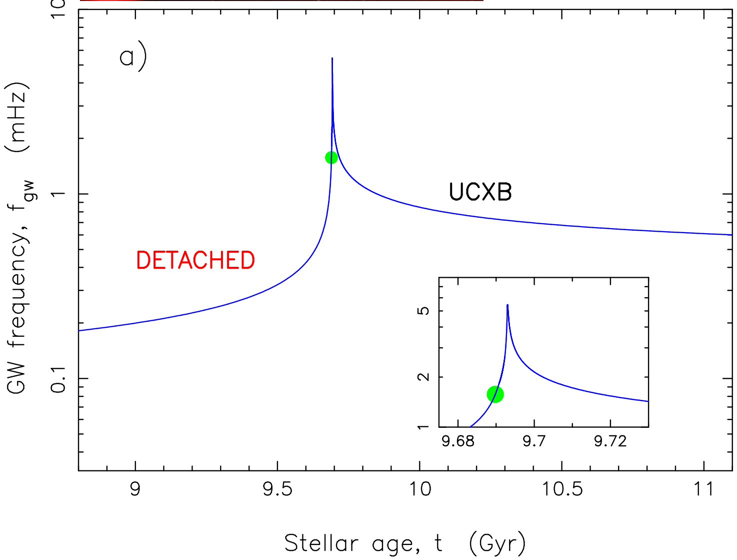


Tauris (2018), Phys.Rev.Lett. 121, 131105

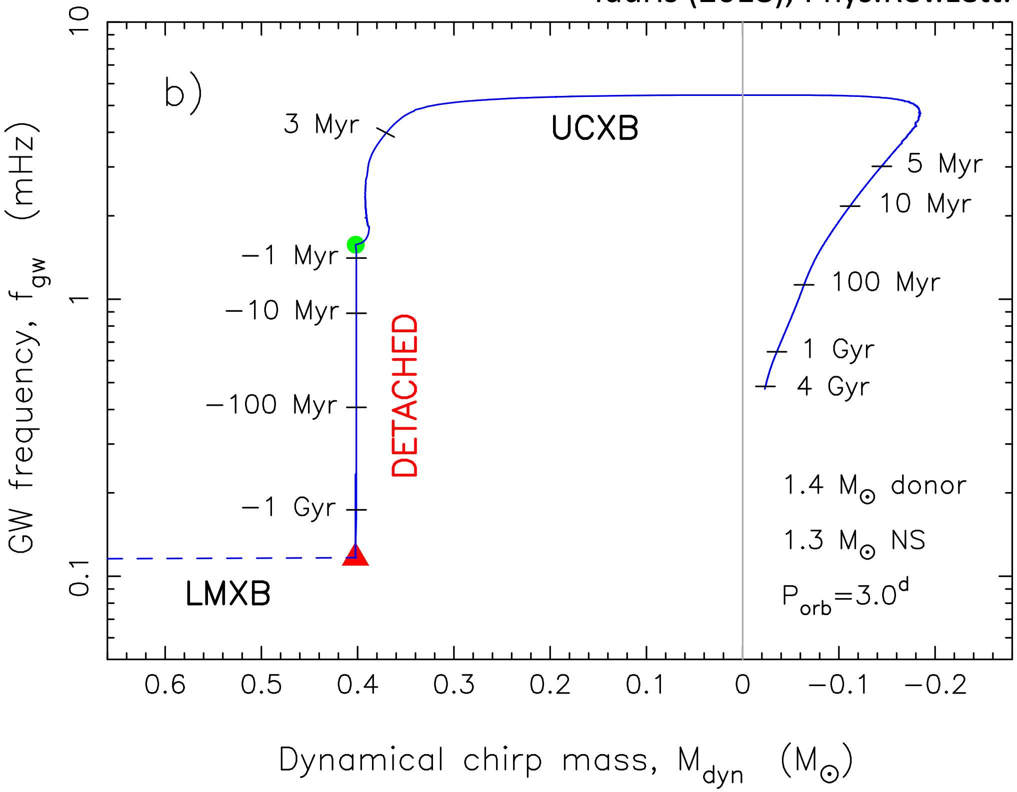
Strong synergies between GWs and EM observations

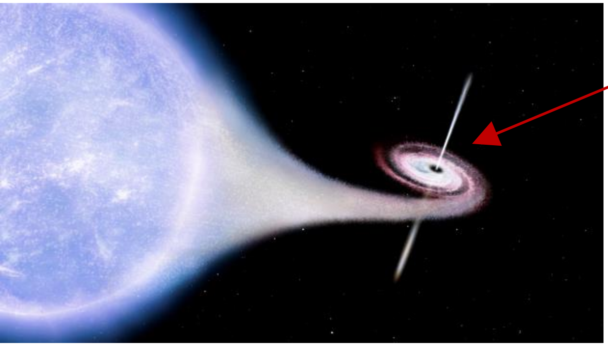
GW SPECTRUM EVOLUTION



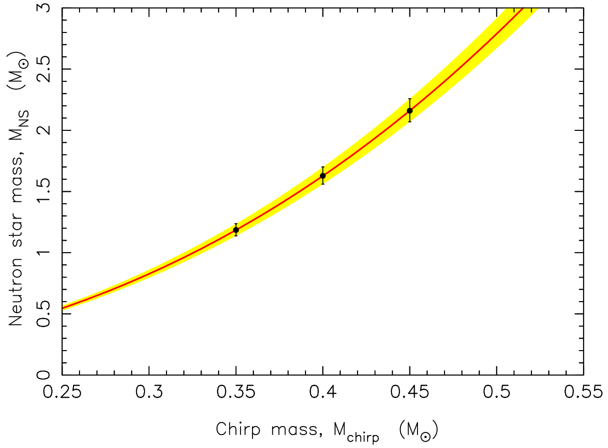


Tauris (2018), Phys.Rev.Lett.

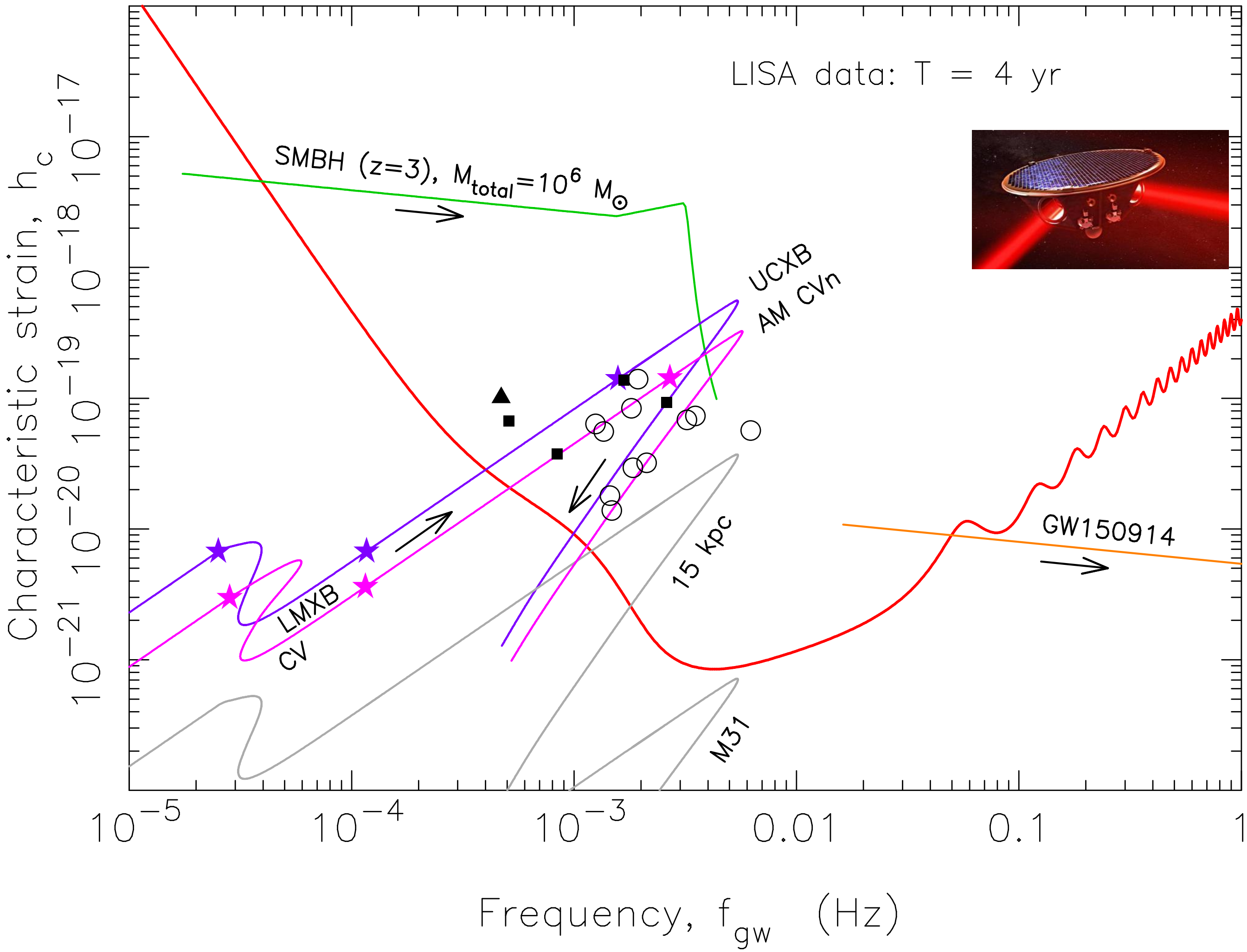




Determine NS mass to a high accuracy (4%) via new method (He WD mass is known!)



DETECTABILITY OF GW SOURCES



Tauris (2018), Phys.Rev.Lett.

$$h_c \approx \sqrt{N_{cycles}}\,\sqrt{2}\,h_0 = \sqrt{2\,f_{gw}T_{obs}}\,h_0 \qquad h_0 = \sqrt{\frac{32}{80}}\,\frac{\pi^{2/3}G^{5/3}\,f_{gw}^{2/3}M_{chirp}^{5/3}}{c^4\,d_L}$$

OBSERVATIONAL CAVEATS

- The **chirp mass** ($\dot{f}_{\rm gw}$) can only be **measured** for LISA binaries with large SNR and which are close to their minimum orbital period where $\dot{f}_{\rm gw}$ is largest.

$$\dot{f}_{\rm gw,min} \sim \frac{4}{T^2}\,\frac{1}{\rm SNR} \simeq 2.5\times 10^{-18}\left(\frac{100}{\rm SNR}\right)\left(\frac{4\ {\rm yr}}{T}\right)^2\ {\rm Hz\,s^{-1}}$$

$$\frac{\Delta\mathcal{M}}{\mathcal{M}} \simeq 3.8\times 10^{-7}\left(\frac{100}{\rm SNR}\right)\left(\frac{4\ {\rm yr}}{T}\right)\left(\frac{1\ {\rm mHz}}{f_{\rm gw}}\right) + 1.6\times 10^{-2}\left(\frac{100}{\rm SNR}\right)\left(\frac{4\ {\rm yr}}{T}\right)^2\left(\frac{10^{-16}\ {\rm Hz\,s^{-1}}}{\dot{f}_{\rm gw}}\right)$$

$\gtrsim 0.005$

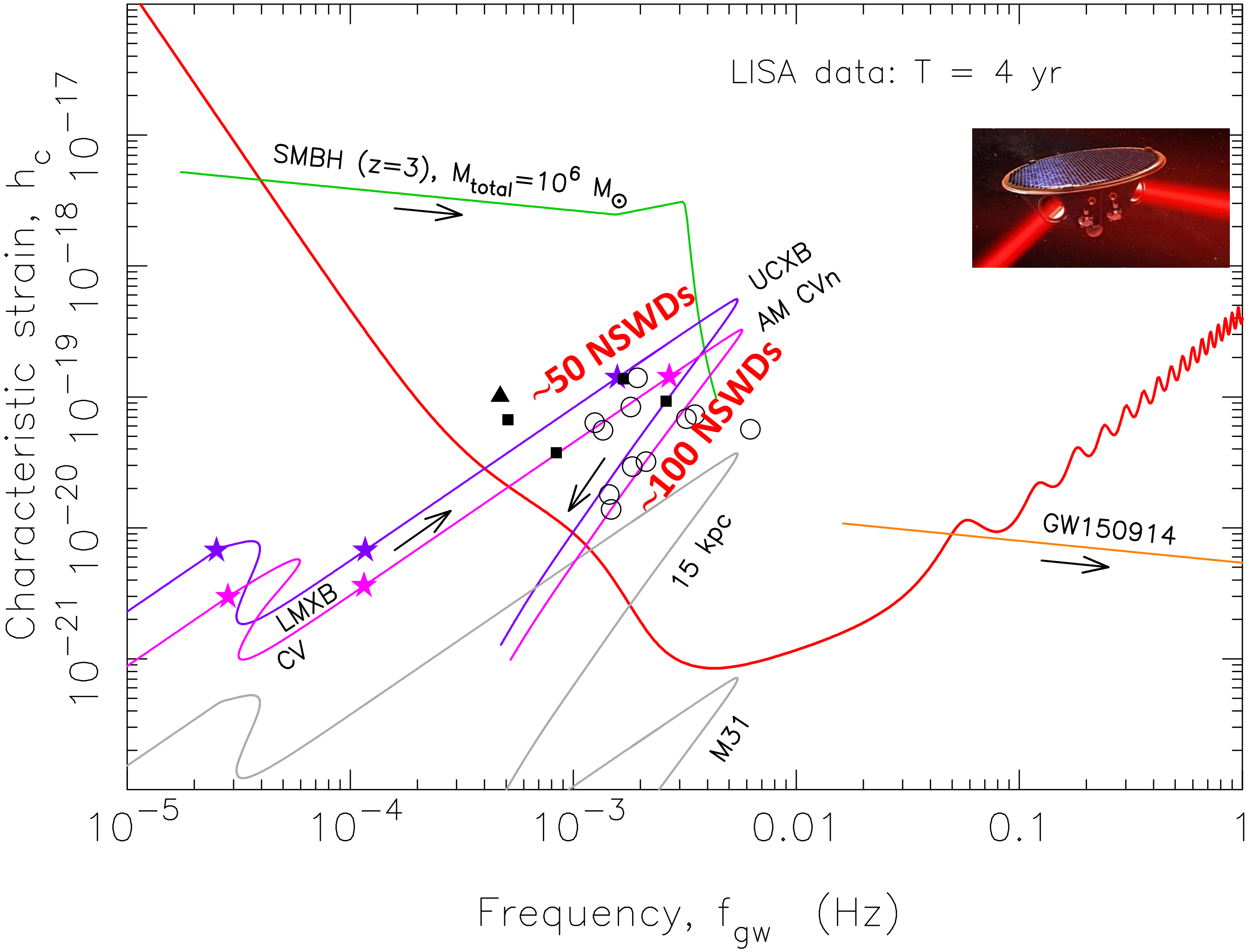
- However, **combining GWs and EM observations** can also be used to get $\dot{f}_{\rm gw}$ e.g. optical observations of WDs or radio pulses from NSs/Fermi sources. (Breivik et al. 2018, Hermes et al. 2012, Abdo et al. 2009).

- It is anitipated that measuring $\dot{f}_{\rm gw}$ is possible for 25% of the resolved LISA sources (Amaro-Seoane et al. 2012).

- **Tidal and mass-transfer interactions, and donor-disk torques**, will most likely not prevent detection of $\dot{f}_{\rm gw}$, but could make it more **challenging** (Kremer et al. 2017, Stroeer & Nelemans 2009, van Haaften et al. 2012, Marsh et al. 2004).

NUMBER OF GALACTIC NSWD GW SOURCES

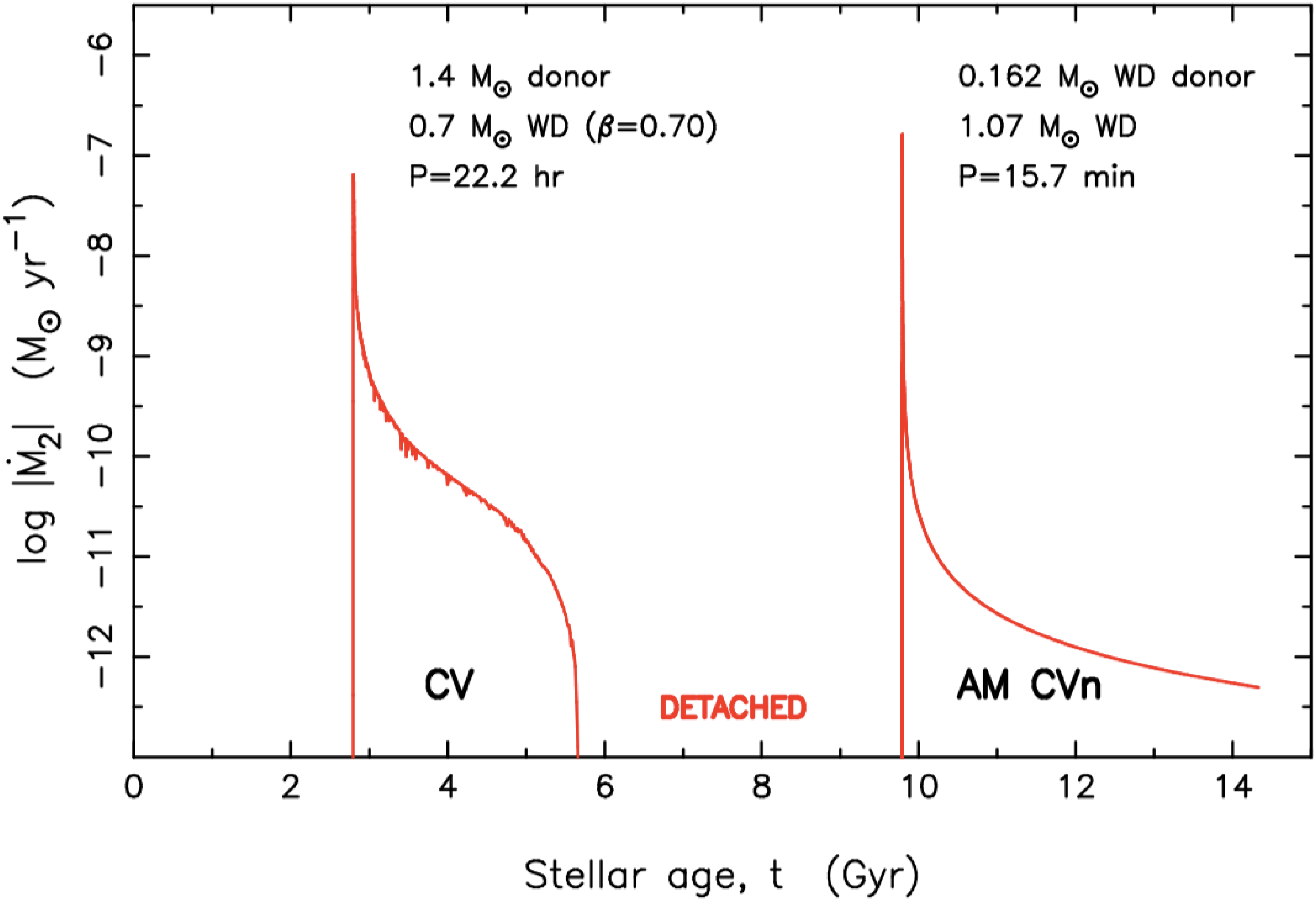
Tauris (2018), Phys.Rev.Lett.



There should be ~150 NSWD binaries detectable in GWs in the Milky Way
(Based on known millisecond pulsars with low-mass He WDs in our Galaxy)

LINKING CVs TO AM CVns

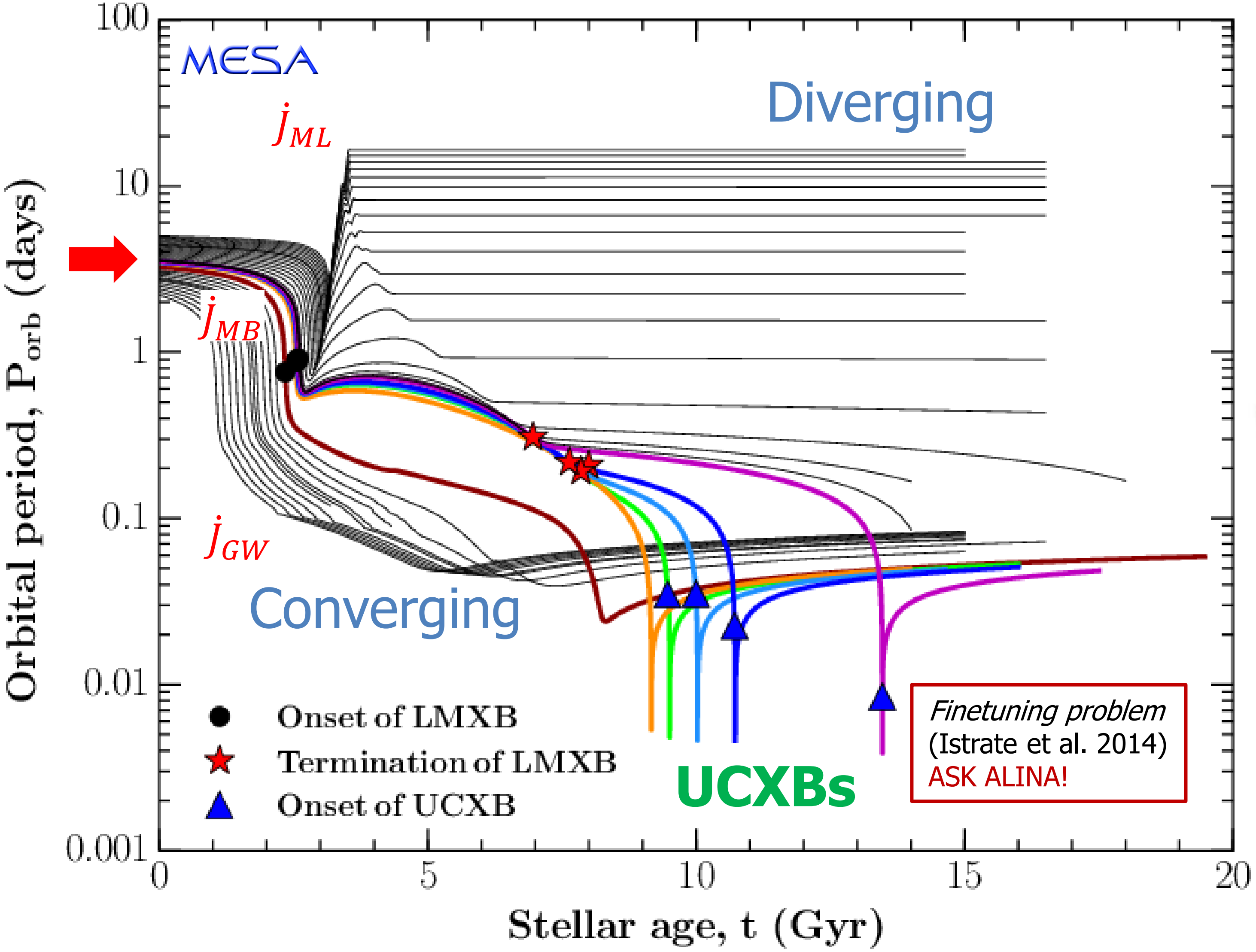
Tauris (2018), Phys.Rev.Lett.



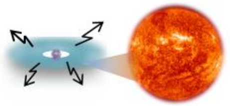
LINKING LMXBs TO UCXBs

$\dot{J}_{ORB} = \dot{J}_{GW} + \dot{J}_{MB} + \dot{J}_{LS} + \dot{J}_{ML}$

Sengar et al. (2017)

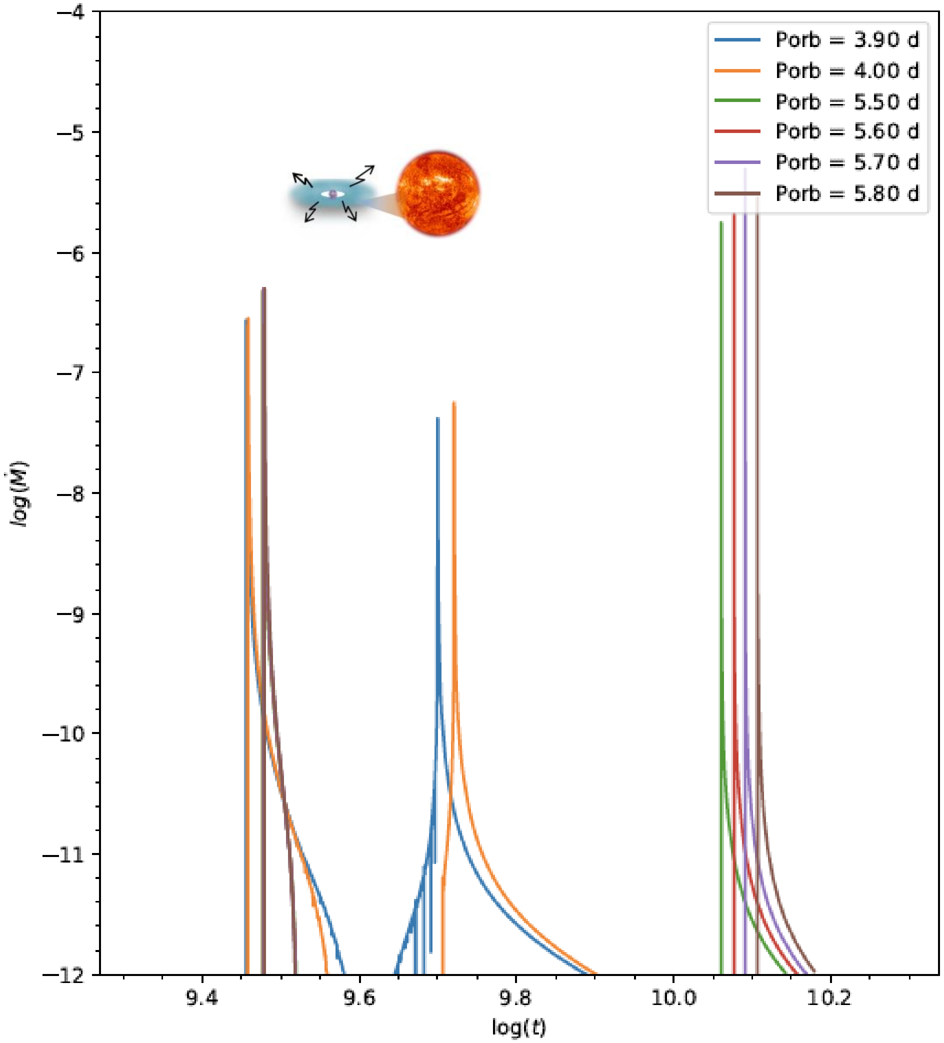


Finetuning problem
(Istrate et al. 2014)
ASK ALINA!



ONGOING THEORETICAL WORK ON GW SOURCES

Computations of Galactic double WD/NS/BH sources and properties for LISA
Post-doc: Hai-Liang Chen



Pre-liminary novel MESA results

- New **magnetic braking** model boosts number of sources in range of initial LMXB P_{orb}
- Trying to reproduce 7 min. and 20 min. WDWD sources…

DUAL-LINE GW BINARY

Discovery of a ***dual-line*** GW binary

Tauris (2018), Phys.Rev.Lett.

NS moment of inertia

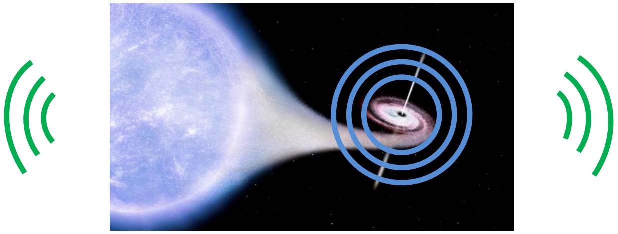
LIGO

$$I_{zz}\,\varepsilon = \sqrt{\frac{32}{80}}\;\pi^{-4/3}G^{2/3}f_{gw}^{-4/3}M_{chirp}^{5/3}\left(\frac{h_{spin}}{h_{orb}}\right)$$

ellipticity

LISA

Independent on the distance to the binary

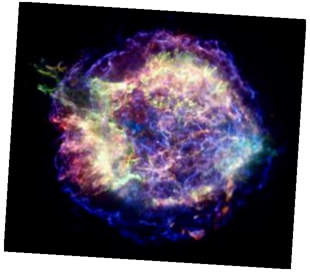


https://ui.adsabs.harvard.edu/abs/2018PhRvL.121m1105T/abstract

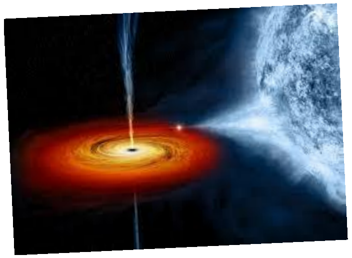
- LISA will provide exciting new insight to close binary evolution.
- Lots of works still to be done for **LISA astroWG** on **Galactic binaries of WD/NS/BH**:
  - **Population** modelling
  - **Physics** on binary star **interactions**
  - **GW signal** modelling (tides, mass-transfer)
- Multi-messenger astronomy: GW and EM obs. of same binaries.
- Synergies:

Stars

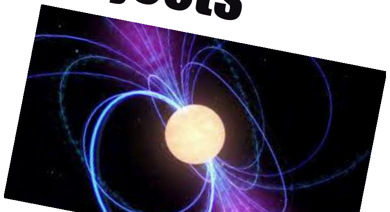
SNe



Binary Interactions



Compact Objects



Gravitational Waves