Can LISA see common-envelope events?

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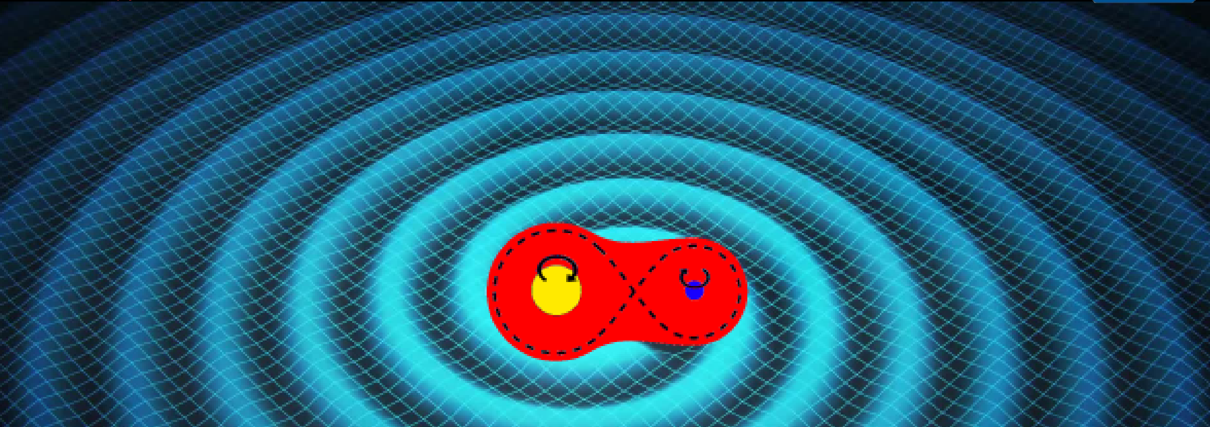
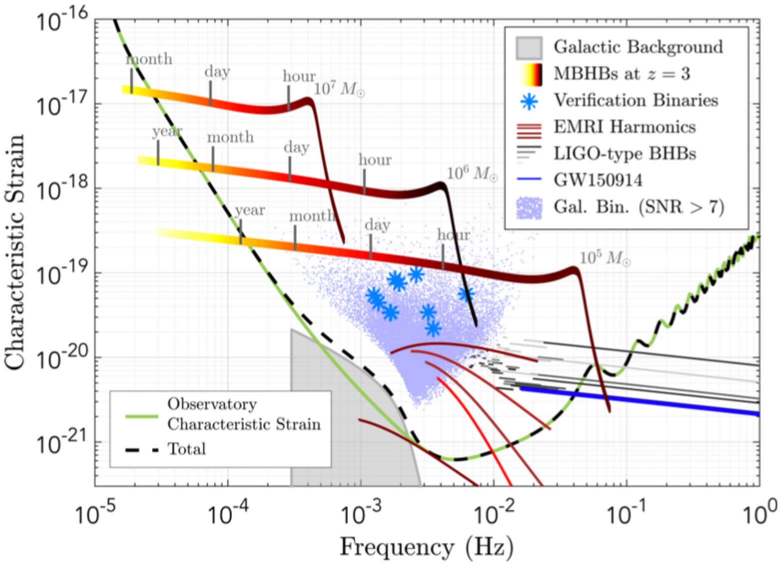
arXiv:2102.00078



LISA can see Galactic double white dwarfs formed via common envelope

⇐ PTA



LIGO/Virgo ⇒

Robson *et al.* 2019

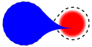
Common Envelope Evolution

Is *not* GW-driven!

But GW passively trace the dynamics

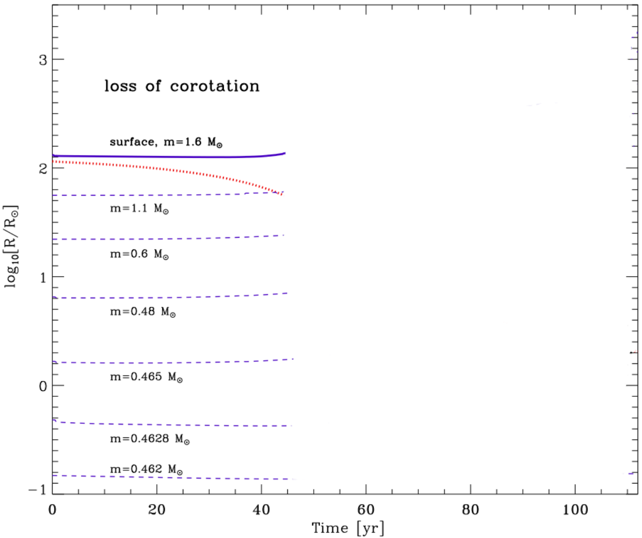
Common envelope evolution in one slide

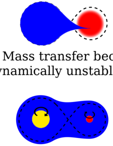
arXiv:2102.00078



a. Mass transfer becomes dynamically unstable

Common envelope evolution in one slide





a. Mass transfer becomes dynamically unstable

b. Loss of corotation between the cores and the envelope

Example from Ivanova *et al.* 13b

Common envelope evolution in one slide

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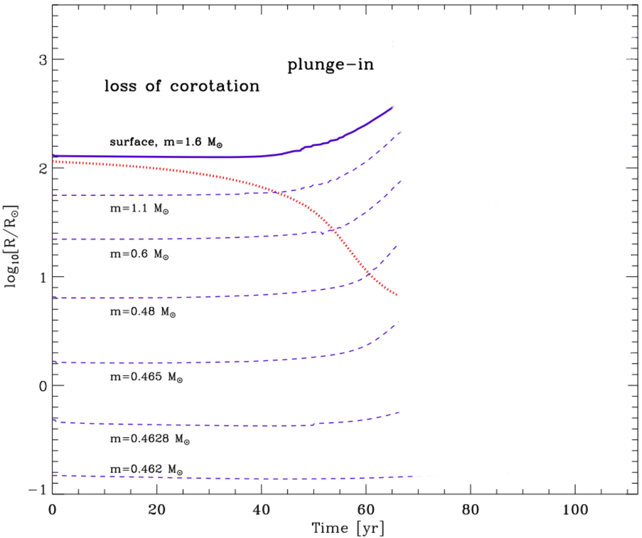

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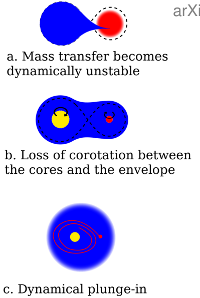

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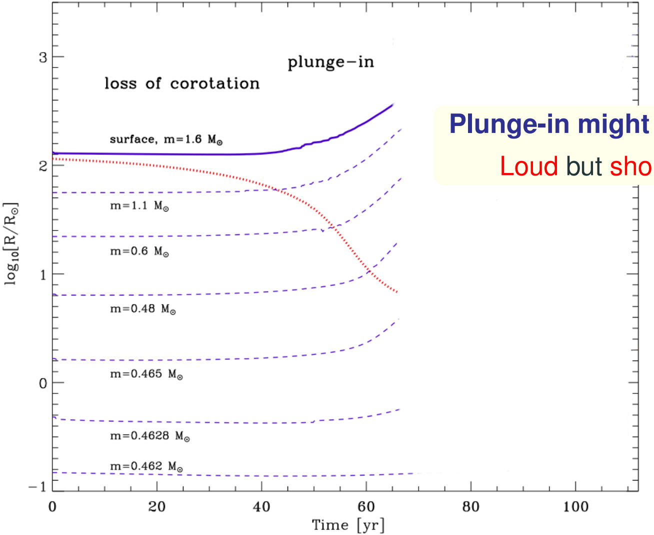

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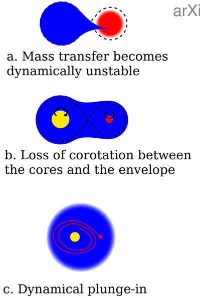
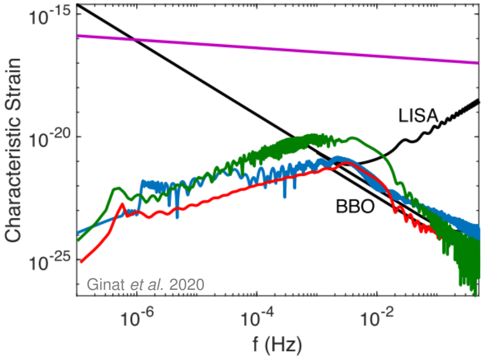


Plunge-in might be detectable

Loud but short and rare



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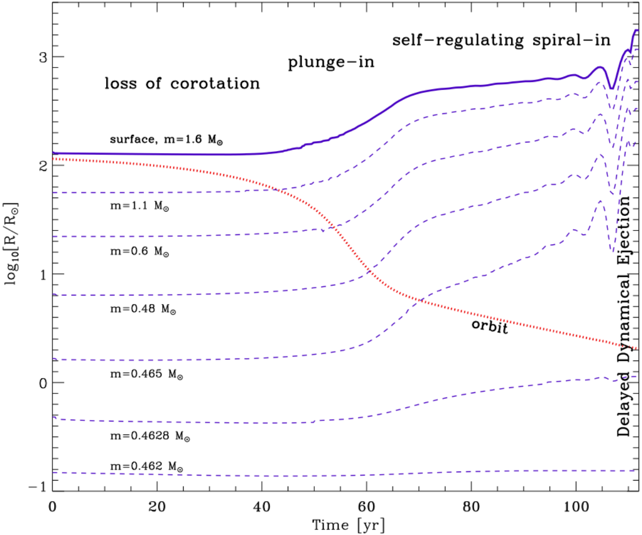
Common envelope evolution in one slide



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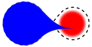
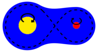
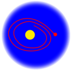


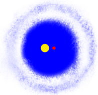
a. Mass transfer becomes dynamically unstable



b. Loss of corotation between the cores and the envelope



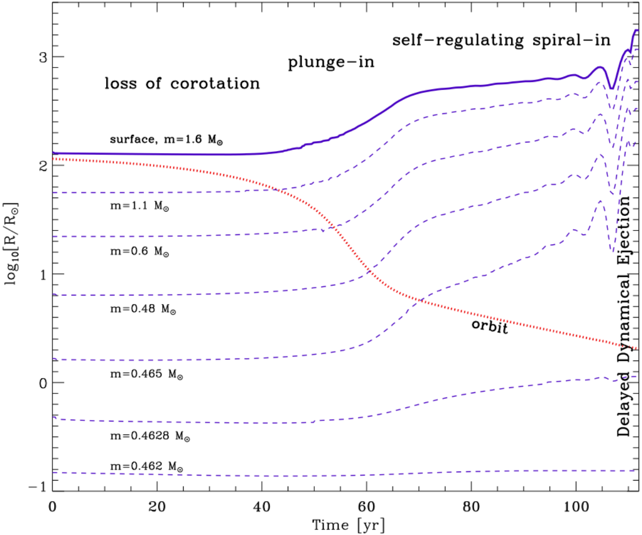
c. Dynamical plunge-in



d. Self-regulated, thermal-timescale inspiral

arXiv:2102.00078

Common envelope evolution in one slide



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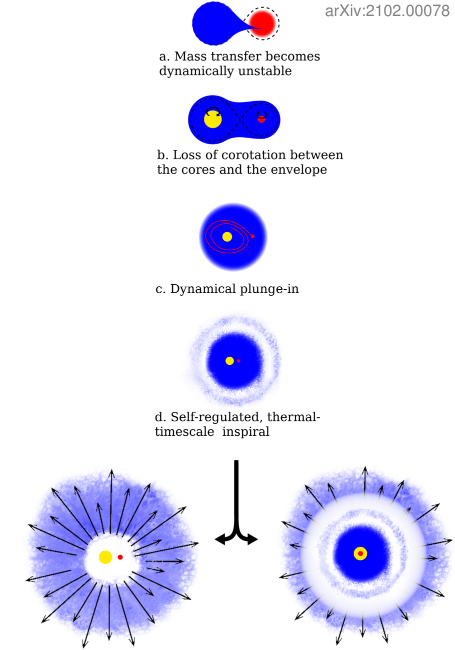

Common envelope evolution in one slide

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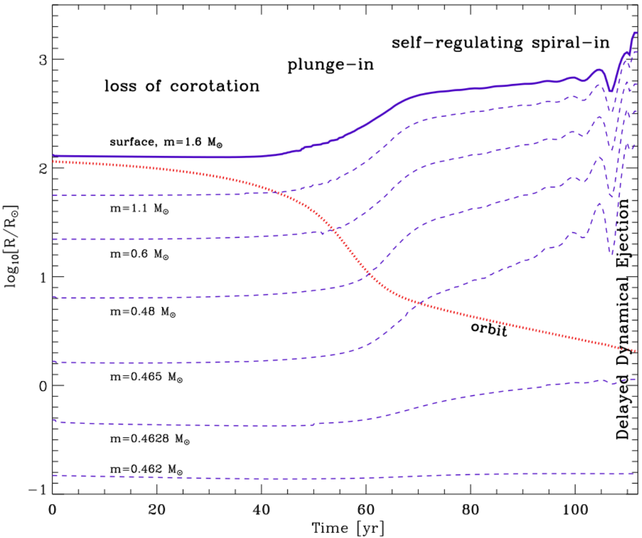

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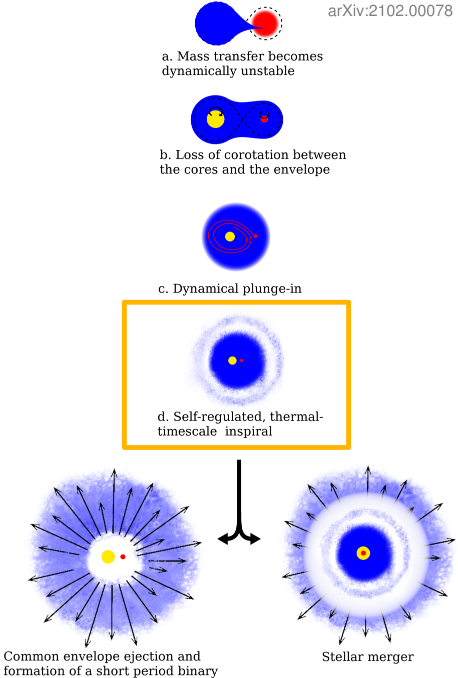

How many sources do we expect?

$$N_{\mathrm{CE}} = R_{\mathrm{CE,init}} \times \Delta t_{\mathrm{CE}}$$

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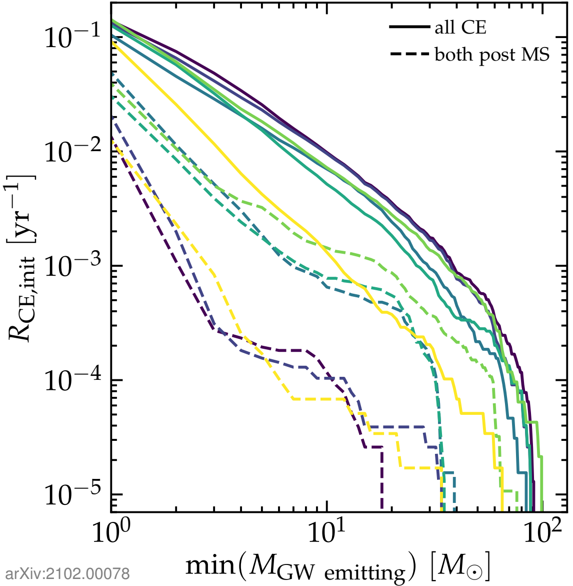

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$$R_{\rm CE,init} = 0.18^{+0.02}_{-0.09} \quad (0.06^{+0.03}_{-0.02})$$

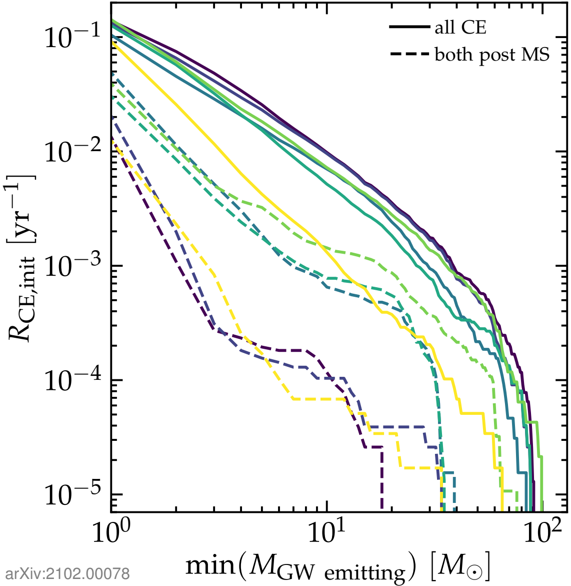
c.f. LRN rate $\sim 0.3\ \mathrm{yr}^{-1}$

Kochaneck *et al.* 14, see also Howitt *et al.* 20

COSMIC

Breivik *et al.* 20

How many sources do we expect? $N_{\rm CE} = R_{\rm CE,init} \times \Delta t_{\rm CE}$



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Duration (in band) is very uncertain

$\Delta t_{\rm CE} \simeq 10^{-2} - 10^5$ years

(e.g., Meyer & Meyer-Hofmeister 79, Fragos *et al.* 19, Igoshev *et al.* 20, Chamandy *et al.* 20, Law-Smith *et al.* 20)

$$\Downarrow$$

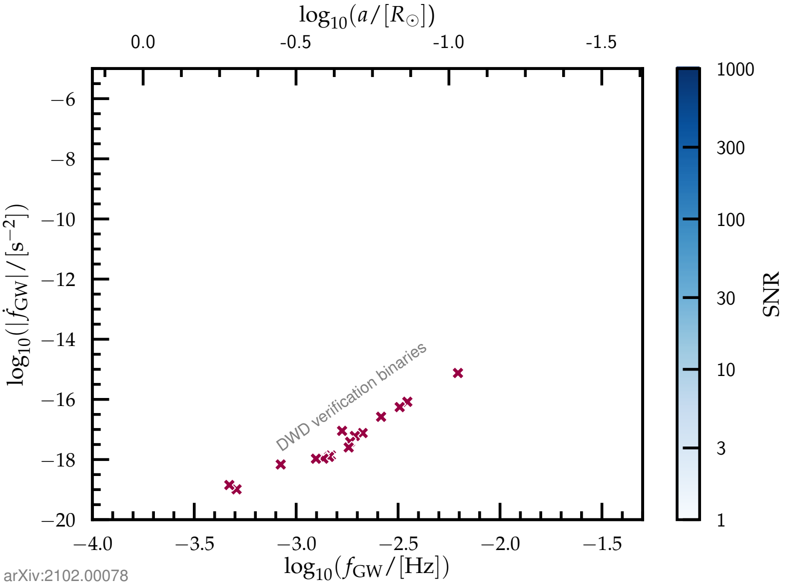
$$0 \lesssim N_{\rm CE} \lesssim 1000$$

COSMIC

Breivik *et al.* 20

Could we detect something?

Could we see it? An answer not relying on a specific model



$M_{core} = 0.5\, M_\odot$, $M_2 = 0.3\, M_\odot$,
$D = 3\,\mathrm{kpc}$, $T = 5$ years,
averaged over
orientation and sky location

arXiv:2102.00078

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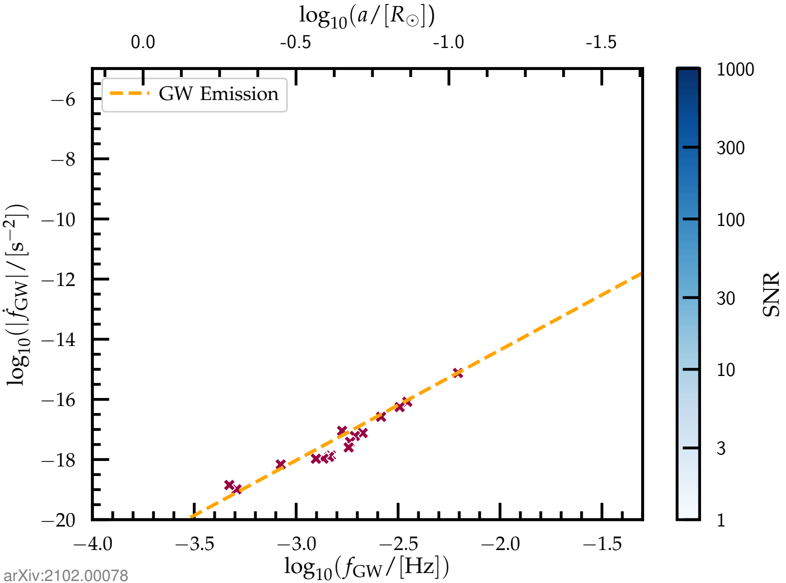

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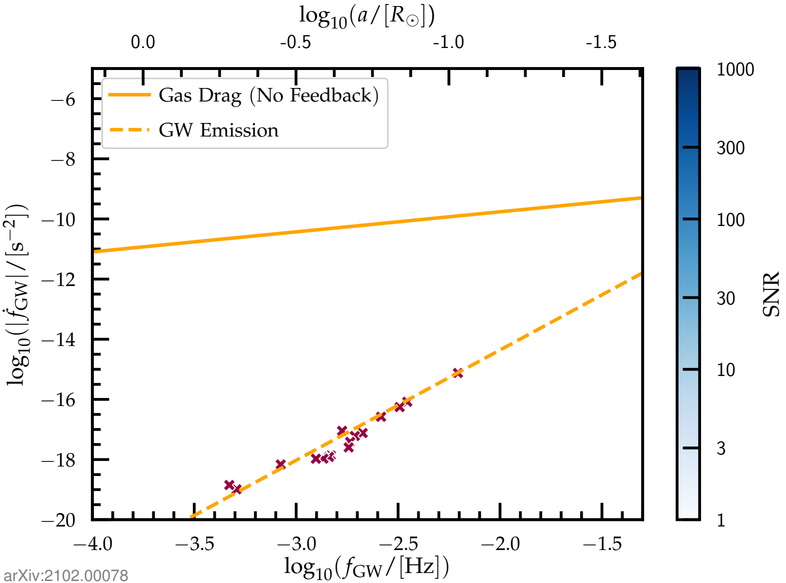

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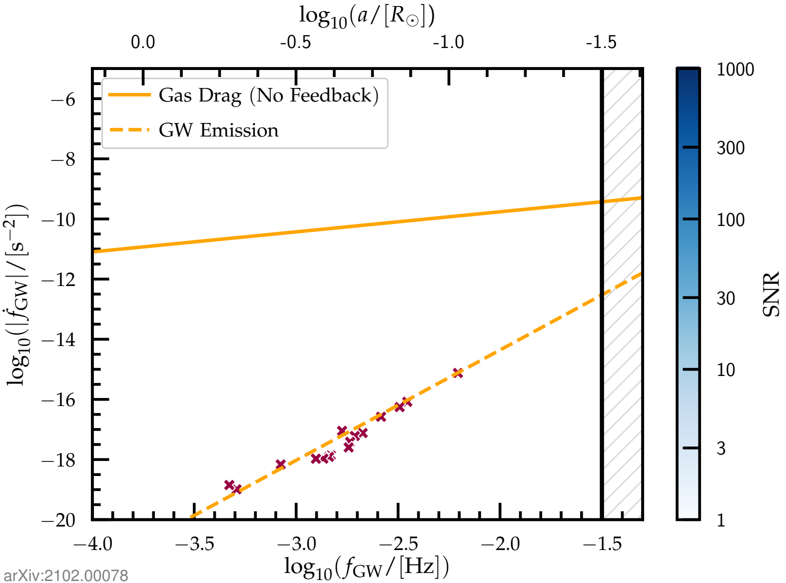

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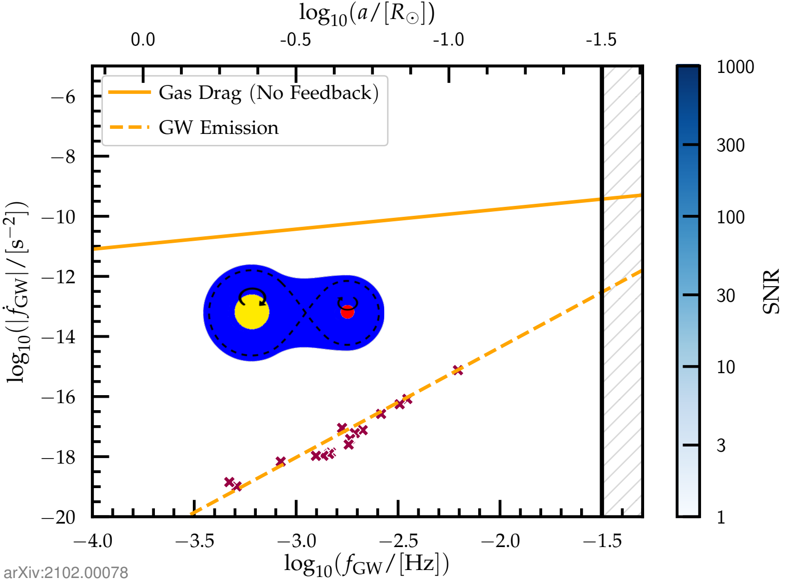

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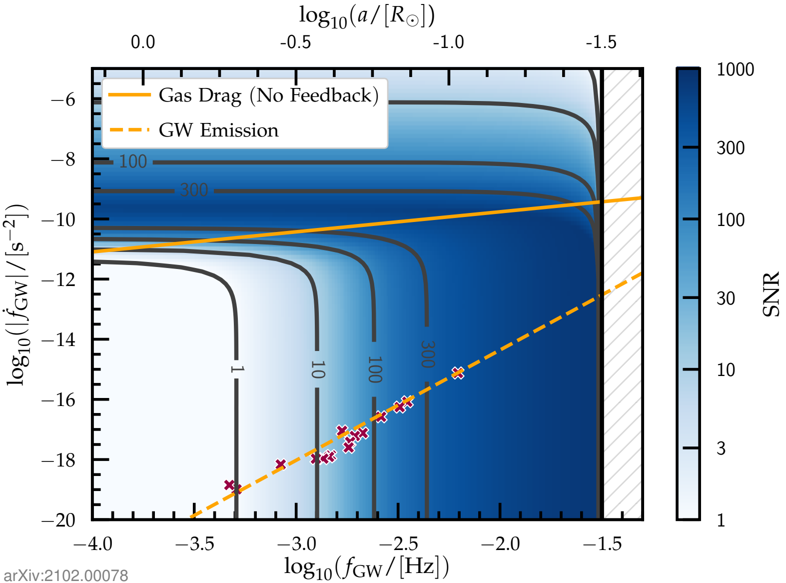

$M_{\rm core} = 0.5\,M_\odot$, $M_2 = 0.3\,M_\odot$,
$D = 3\,{\rm kpc}$, $T = 5$ years,
averaged over
orientation and sky location

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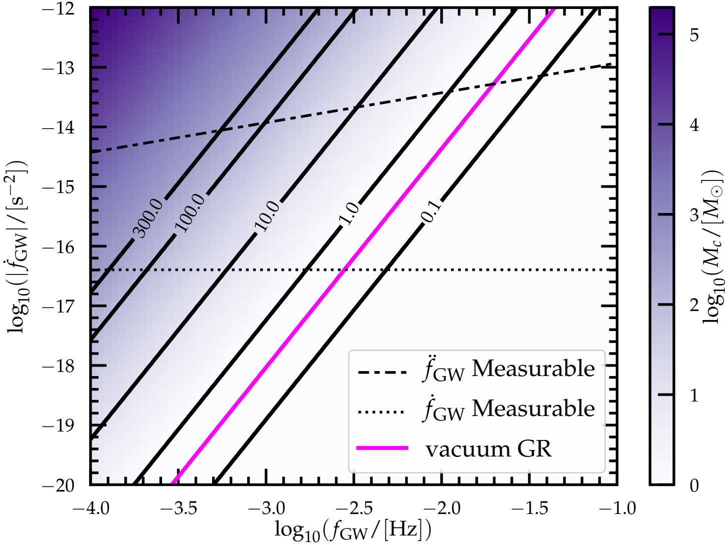
Would we recognize GWs from common envelope?

"Stealth bias" assuming GR in vacuum: chirp mass



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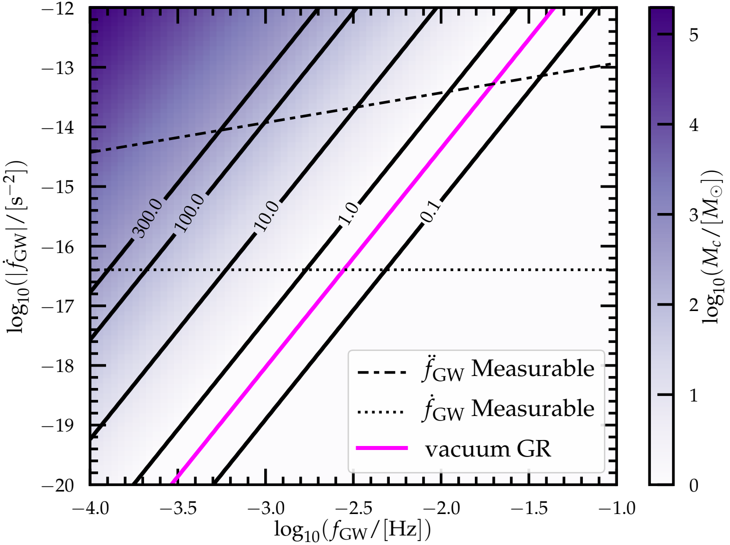
“Stealth bias” assuming GR in vacuum: chirp mass

“Braking index”

$$n = f\ddot{f}/\dot{f}^2$$

$$\Downarrow$$

$$n_{\rm GR} = \frac{11}{3}$$



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"Stealth bias" assuming GR in vacuum: chirp mass

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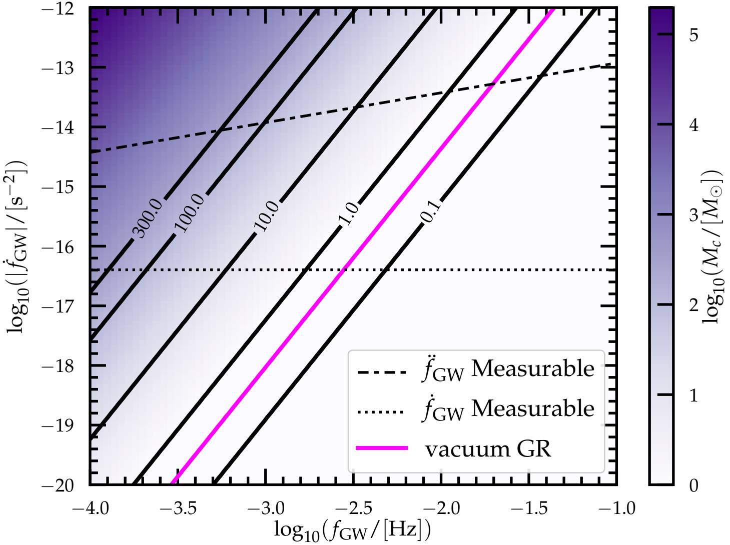
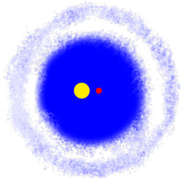




EM counterparts:

- Optical/IR transients

  (Blagorodnova *et al.* 20)

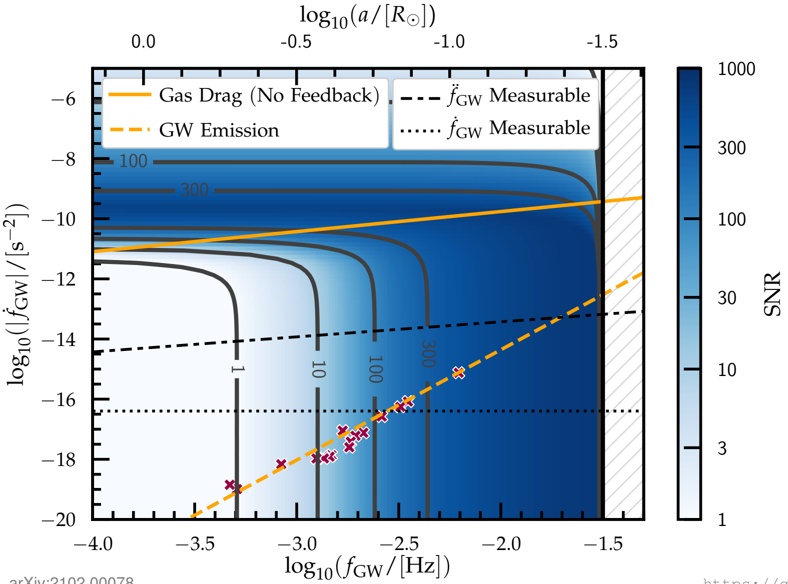
- "weird" red giant star

  (Clayton *et al.* 17)

arXiv:2102.00078

Conclusions

Can LISA see common-envelope events? Maybe!



- $\sim$ One CE-begin per 10 yr
- $0 \lesssim N_{CE} \lesssim 1000$
- if stalls at short separation they might detectable

$\Downarrow$

Direct window on the inside

If non-detection

- stalls at large separation

and/or

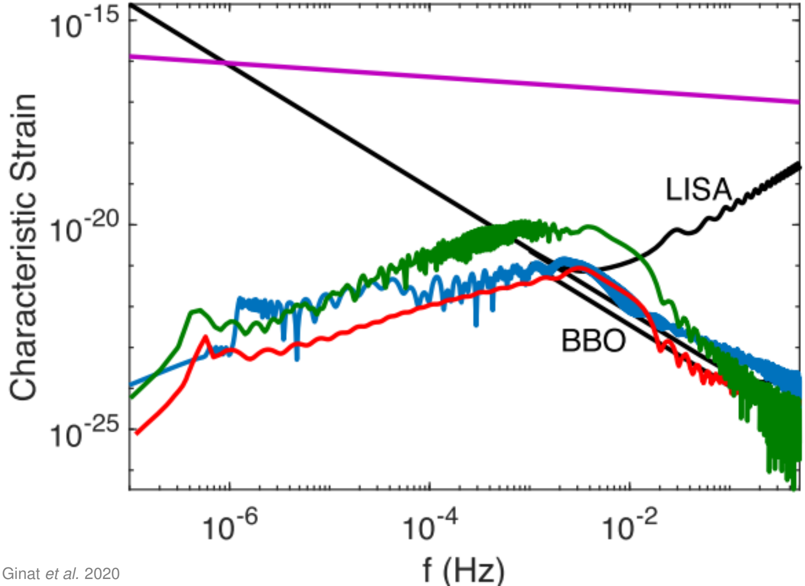
- stalling phase is short

arXiv:2102.00078

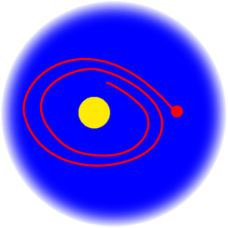
https://github.com/tcallister/LISA-and-CE-Evolution

Backup slides

Dynamical phases are loud but short and thus rare

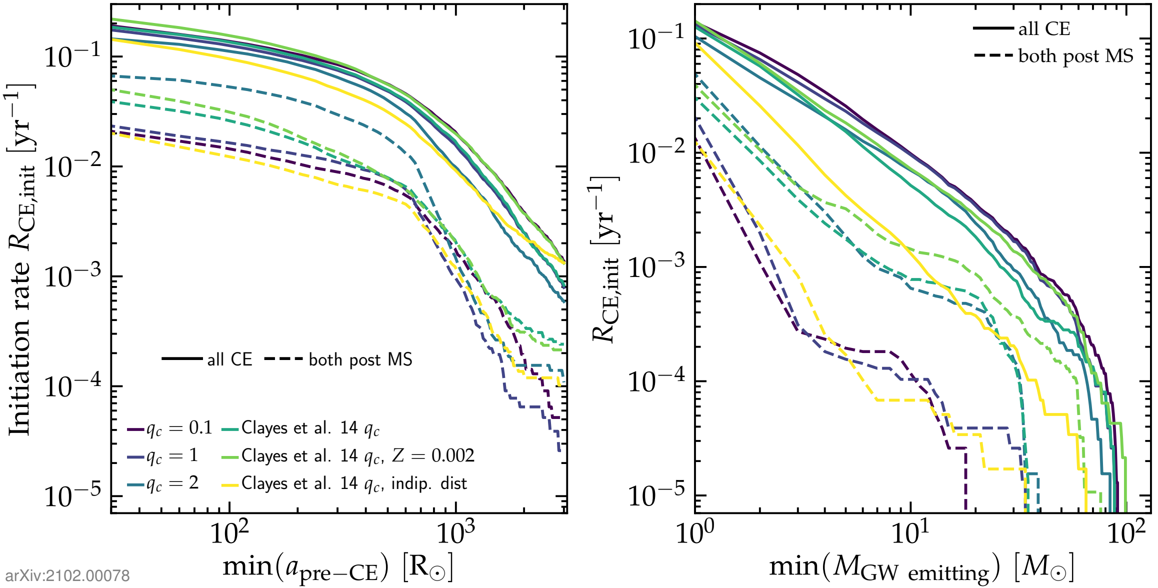


Ginat *et al.* 2020



Requires massive donor star

Rate of common-envelope initiation with pre-CE separation



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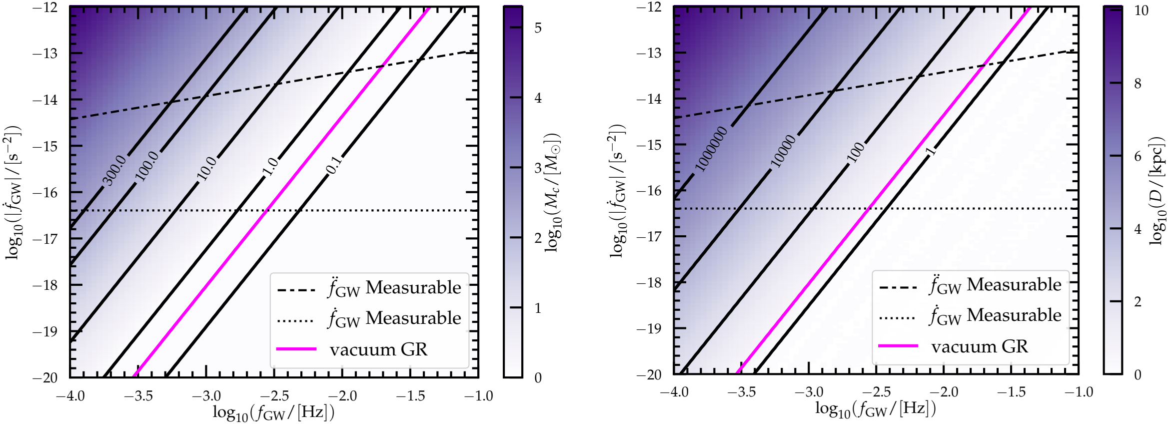
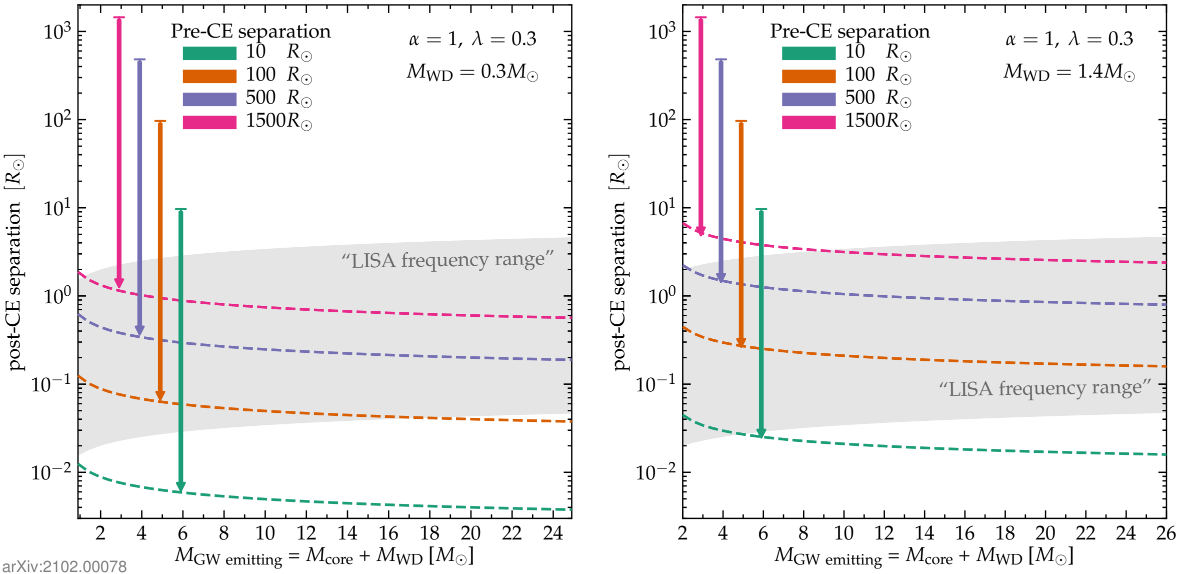
"Stealth bias" assuming GR in vacuum: chirp mass & distance



"Braking index" $n = f\ddot{f}/\dot{f}^2 \Rightarrow n_{\rm GR} = \frac{11}{3}$

arXiv:2102.00078

Most common envelope events cross the LISA band



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LISA planned launch ∼ 2034

Other mHz GW detectors planned

e.g., TianQin