Full and repeated TDEs

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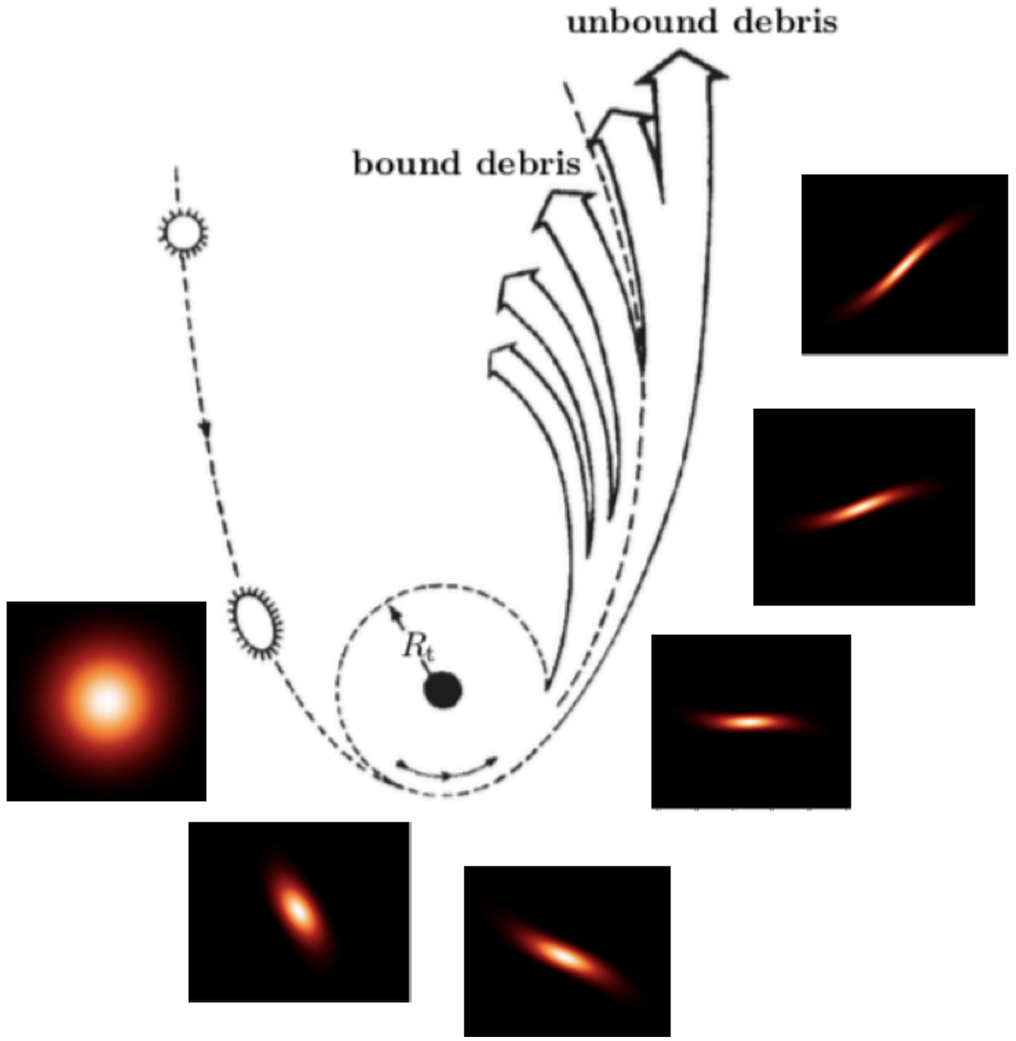
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

TDEs



(Original image from Rees88. Snapshots produced by Toscani using PHANTOM (Price+18)

Stars tidally disrupted by BH tides (Rees88, Phinney89. Recent:: Ryu+20, Rossi+21, Bonnerot & Stone 21)

Multimessenger emitters

- Luminous electromagnetic flares (reviews: Saxton+20, vanVelzen+20, Alexander+20)
- High energy neutrinos

  (Hayasaki21, Stein22, Reusch+22,)
- GWs (Kobayashi+04, **Toscani**+19,20,22,23, Pfister,**Toscani**+22)

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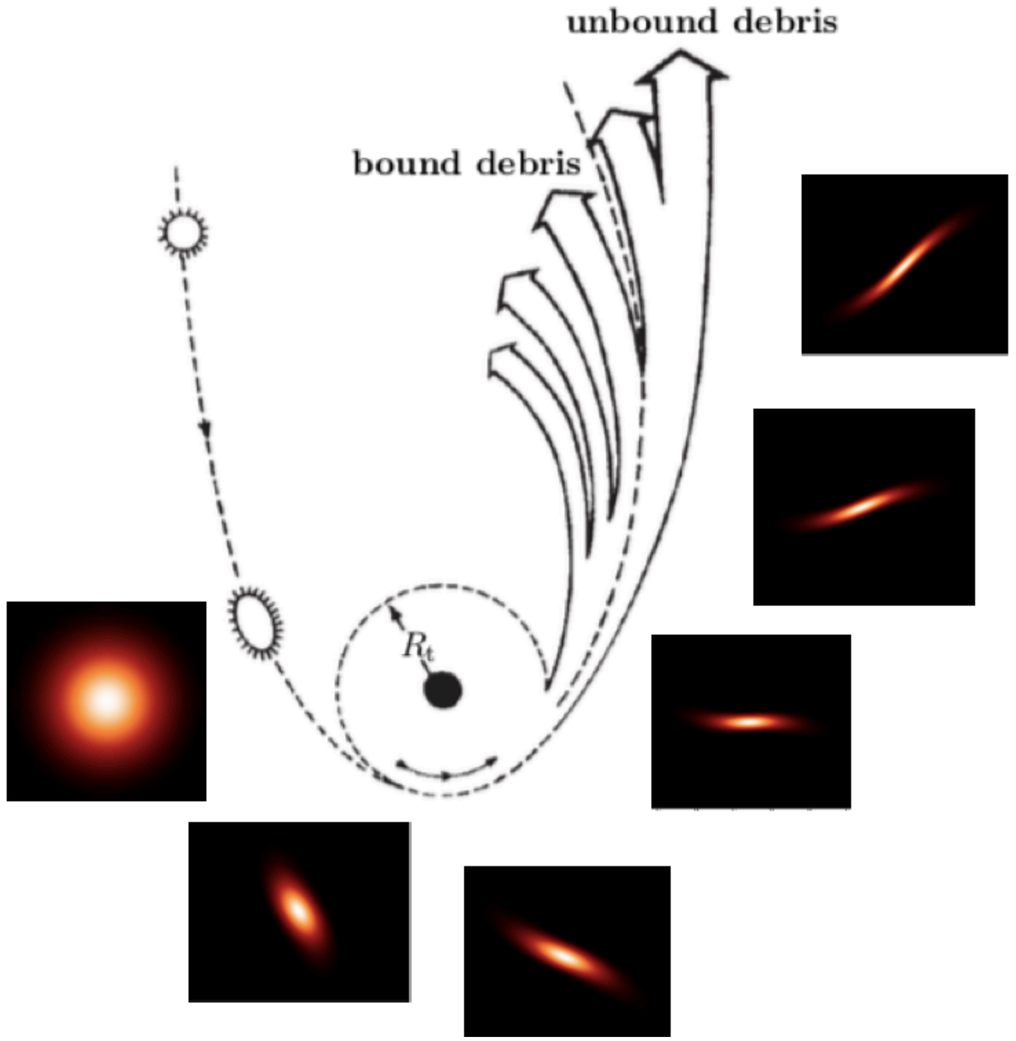
TDEs



(Original image from Rees88. Snapshots produced by Toscani using PHANTOM (Price+18)

- Refine estimates of Pfister, Toscani+22 and Toscani+20 considering all the harmonics of the signal (formalism by Berry&Gair10)

- Distinction between full TDEs and repeated partial TDEs

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fTDEs: main sequence stars

$$\frac{d^4\dot{N}^{\rm fTDEs}_{\rm det}}{dz dM_\bullet dM_* dR_{\rm p}} \approx \frac{d^2\Gamma(M_\bullet)}{dM_* dR_{\rm p}} \times \Phi(M_\bullet, z) \times \frac{4\pi\chi^2(z)}{H(z)} \times \Theta(z, M_\bullet, M_*, R_{\rm p})$$

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fTDEs: main sequence stars

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Massive BH mass function

(Davidzon et al. 2017, Reines & Volonteri)

Comoving volume

(Hogg 1999)

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fTDEs: main sequence stars

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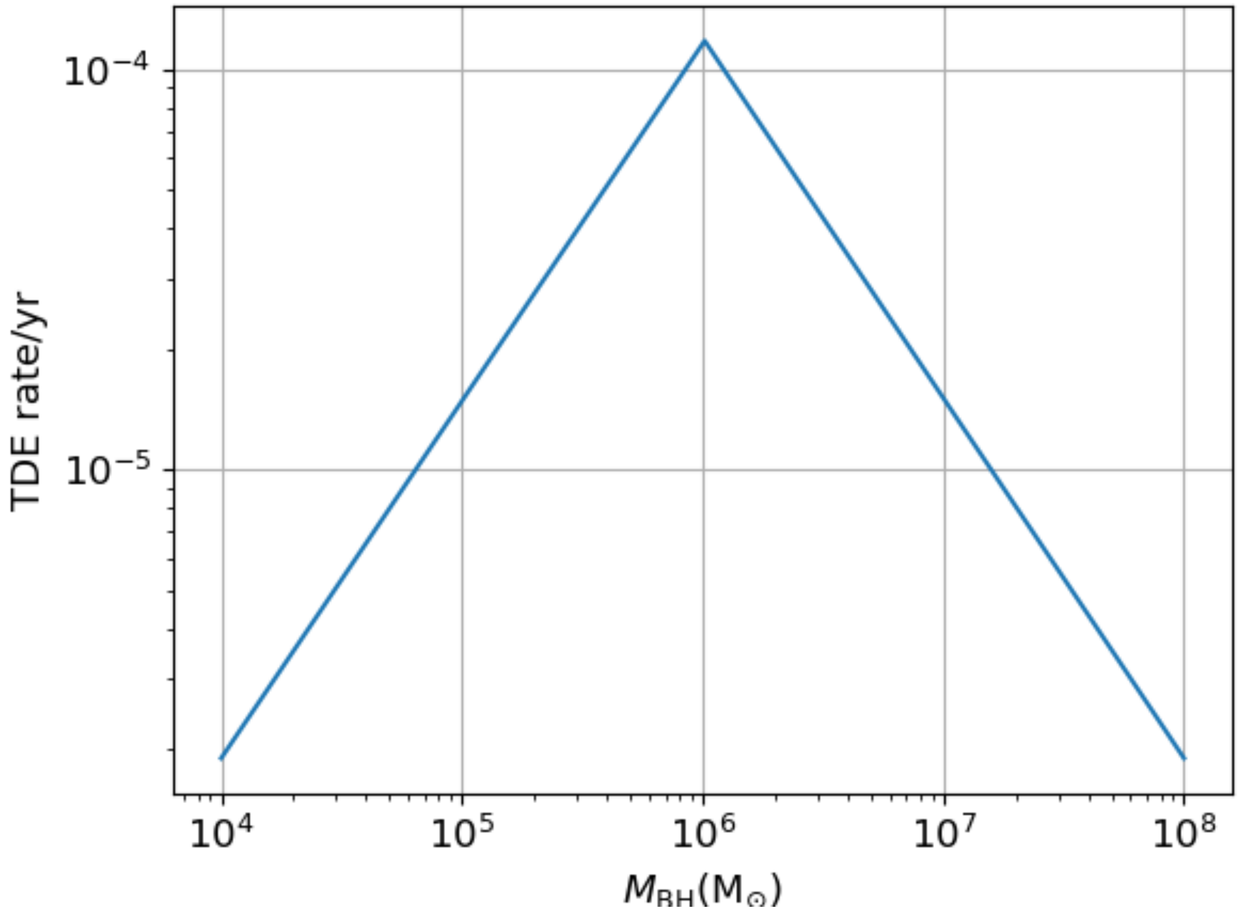
$$\frac{d^2\Gamma(M_\bullet)}{dM_* dR_{\rm p}}$$

→ Chang et al. 2024

→ Broggi et al. 2024



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fTDEs: main sequence stars

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$$\Theta(z, M_\bullet, M_*, R_{\rm p}) \longrightarrow {\rm SNR}^2 = 4\int_0^\infty df \frac{\tilde{h}(f)^{\,2}}{Sn_{\rm n}(f)}$$

Harmonics

Instrument

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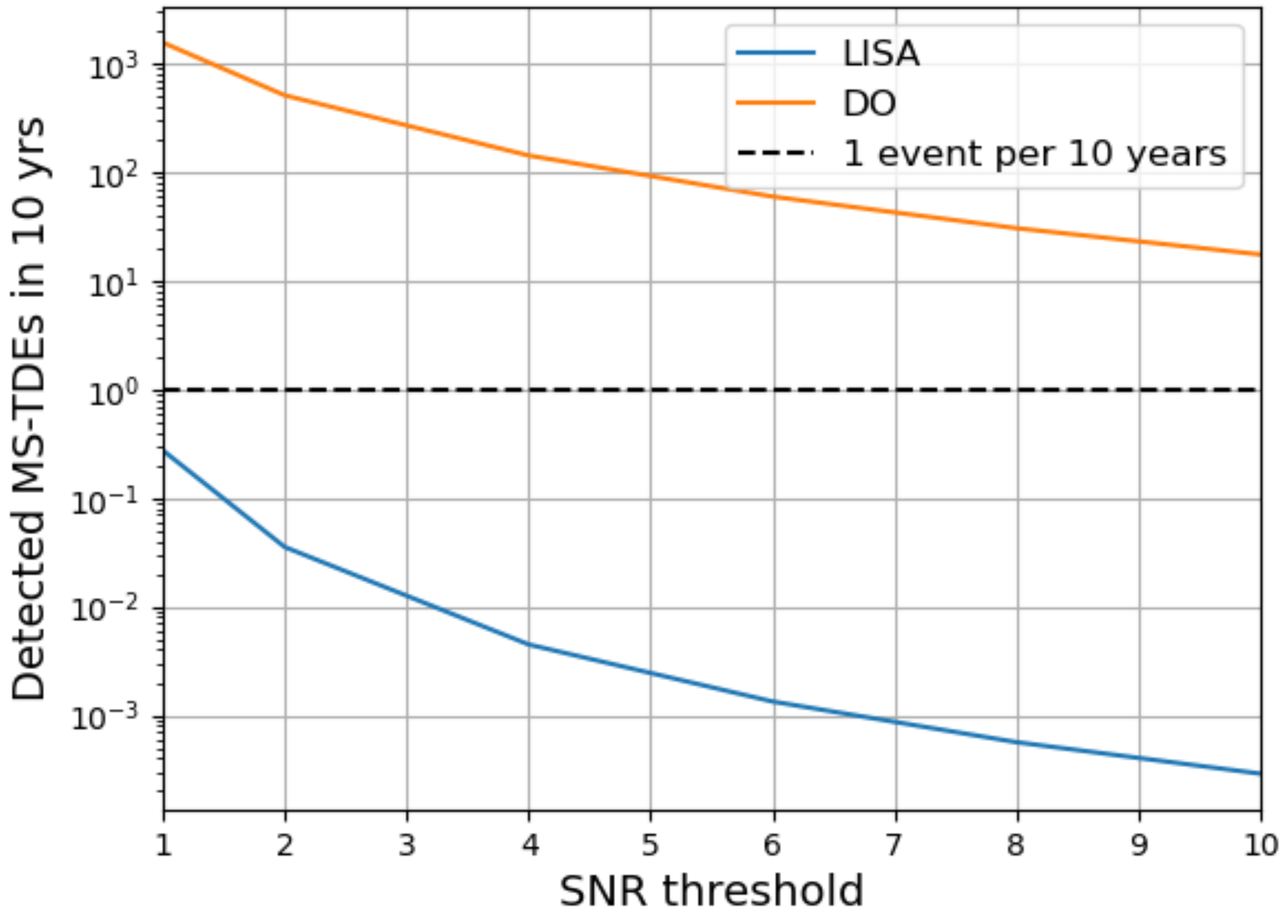
fTDEs: main sequence stars

$$0.1\mathrm{M}_\odot \leq M_* \leq 10\mathrm{M}_\odot, 10^4\mathrm{M}_\odot \leq M_\bullet \leq 10^7\mathrm{M}_\odot, 10^{-4} \leq z \leq 3$$



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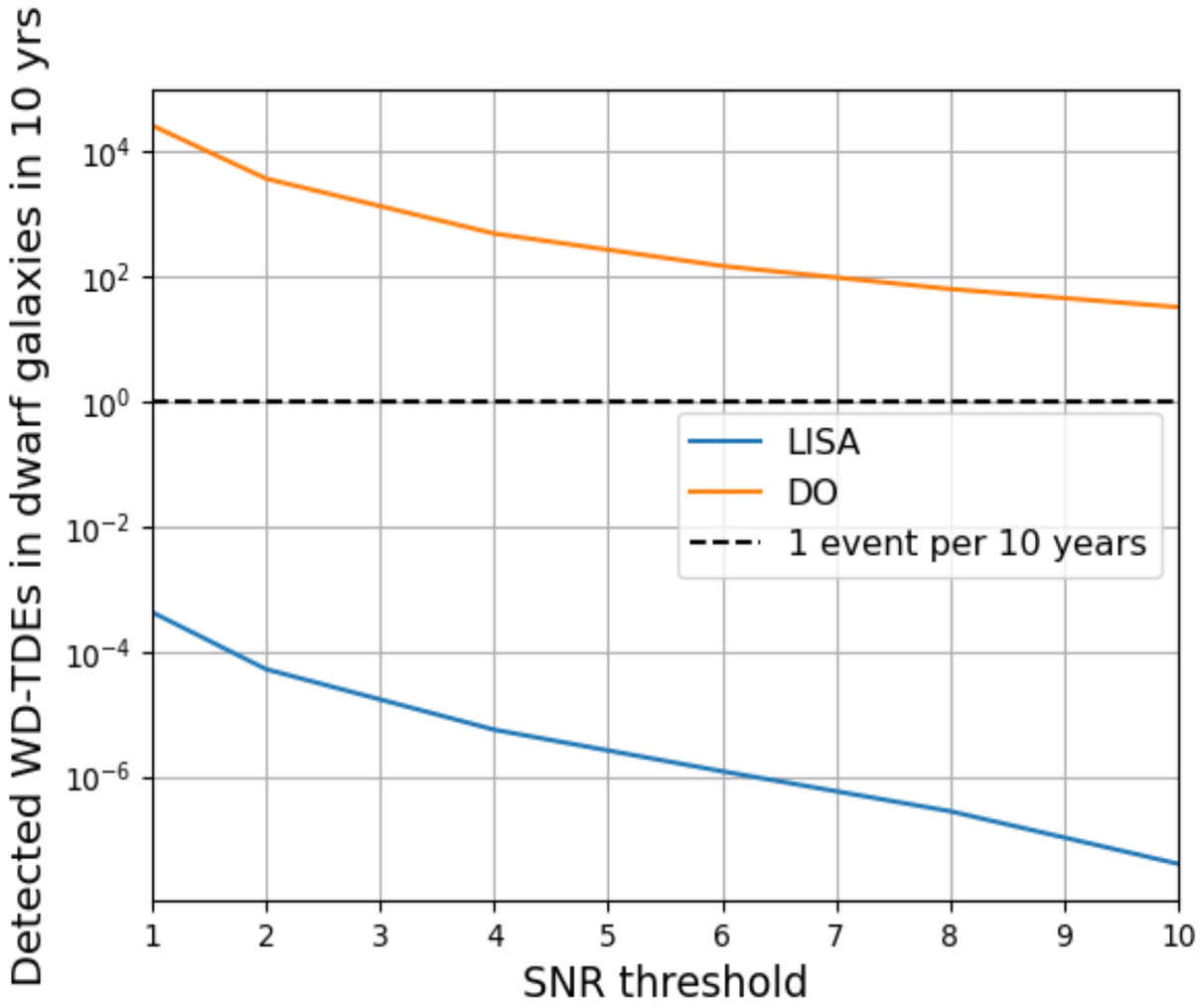
fTDEs: white dwarfs

$$M_* = 0.5\mathrm{M}_\odot, 10^3 \leq M_\bullet \leq 10^5\mathrm{M}_\odot, 10^{-4} \leq z \leq 3$$



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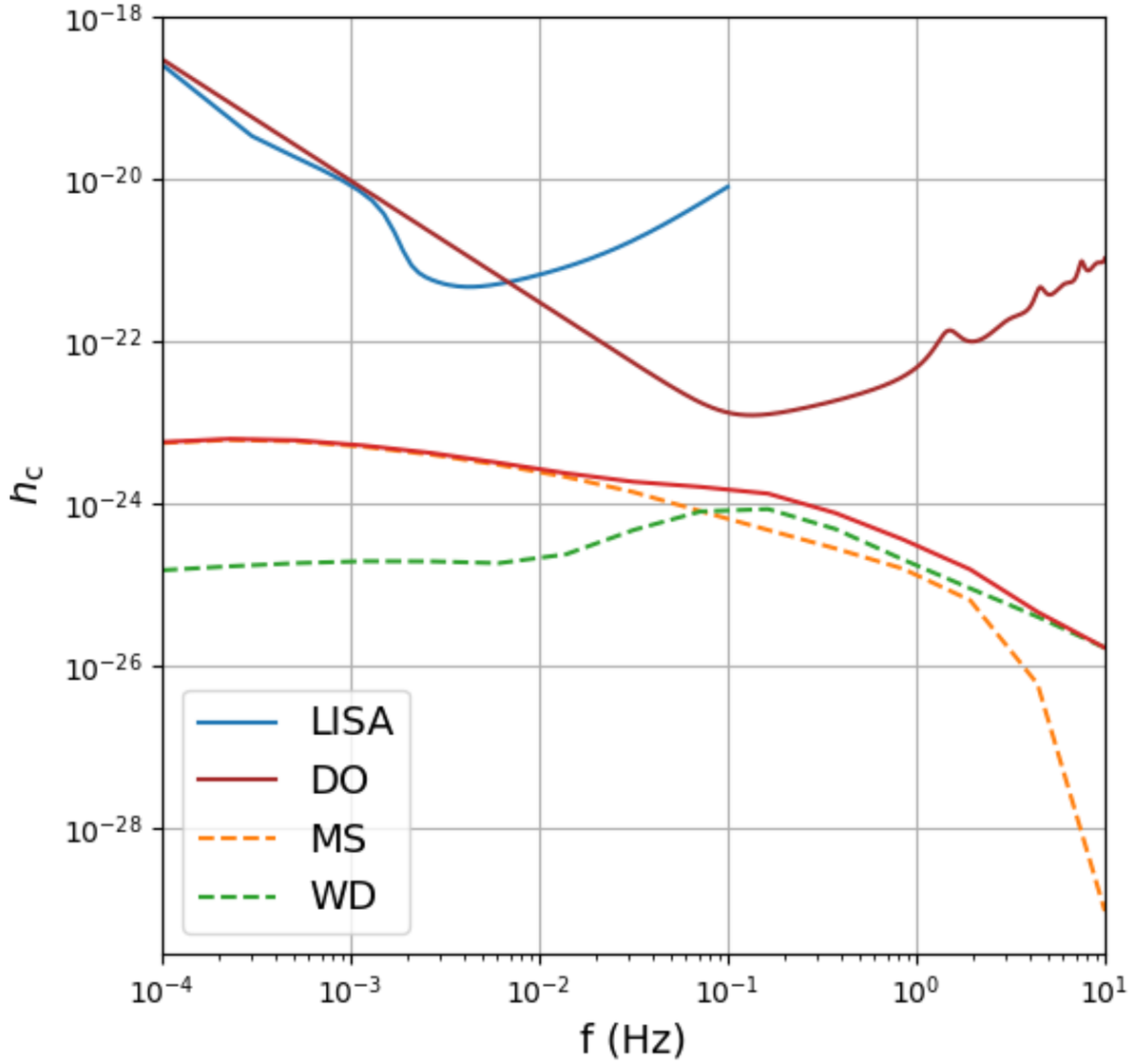
GW background from fTDEs



$$h^2_{\rm c,pop} = \frac{G}{c^3\pi^2} \times \frac{1}{f} \times \int_0^\infty dz \frac{d\dot{N}^{\rm tde}}{dz} \times \frac{1}{\chi^2(z)} \frac{1}{1+z} \left(\frac{dE}{df} \right)$$

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rpTDEs: background

$$h^2_{\rm c,pop} = \frac{G}{c^3\pi^2} \times \frac{1}{f} \times \int_0^\infty dz \frac{d\dot{N}^{\rm tde}}{dz} \frac{1}{\chi^2(z)} \frac{1}{1+z} \left(\frac{dE}{df}\right)$$

Population of 1Msun stars disrupted by $10^5 - 3\times10^5 - 4\times10^6 M_\odot$ (Broggi et al. 2024)

- two-body scattering
- number orbits per energy bin
- pericenter for total disruption

$$\frac{d\dot{N}}{dz} = \int d\epsilon \frac{d\dot{N}}{dz d\epsilon} = \int d\epsilon \frac{d\dot{N}}{d\epsilon} \frac{4\pi c \chi^2(z)}{H_0} \Phi(z)$$

$$\frac{dE}{df} = \sum_{i=1}^{N_{\rm orbs}(\Delta\epsilon_j)} \left.\frac{dE}{df}\right|_i$$

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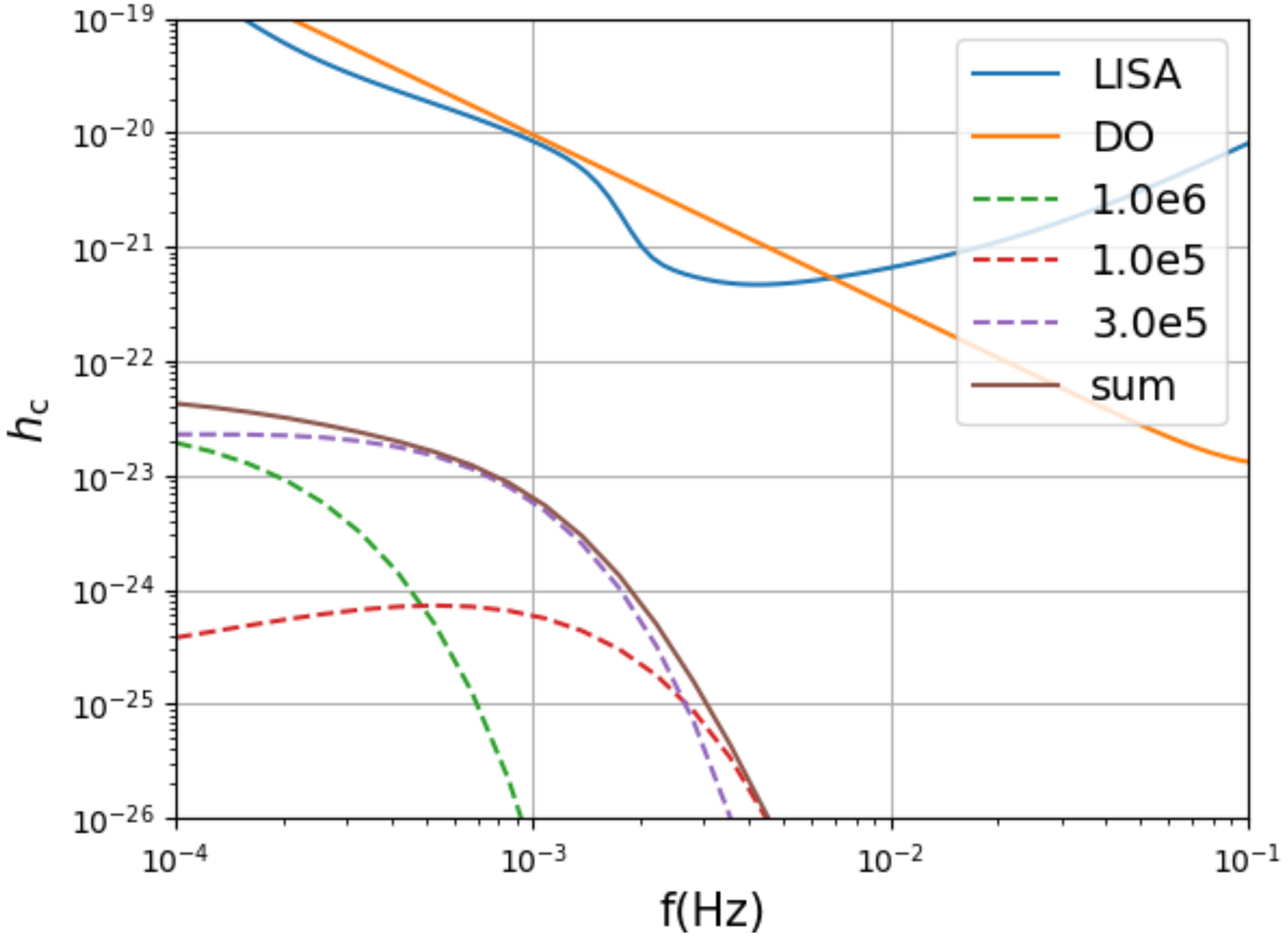
rpTDEs: background



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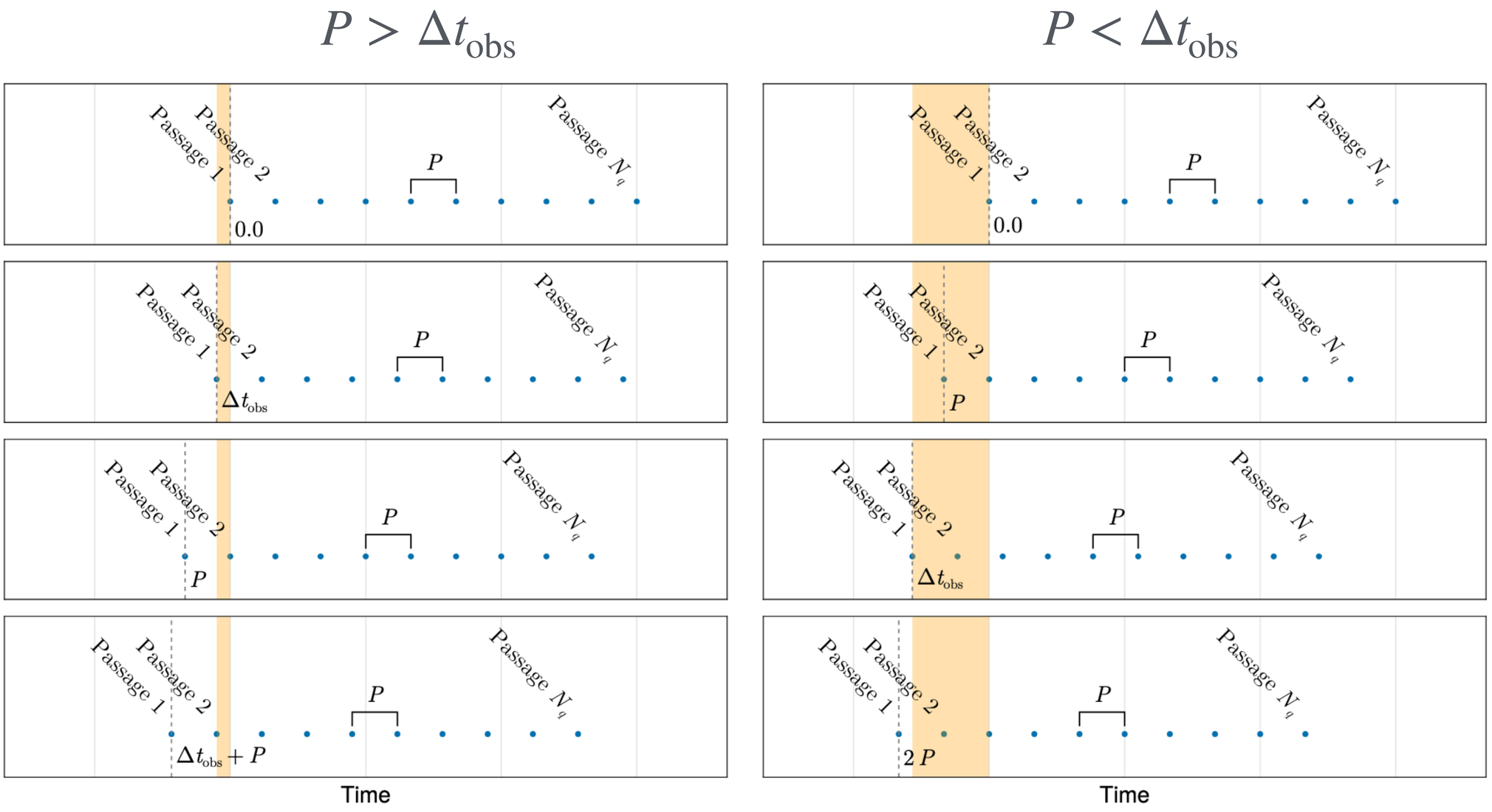
rpTDEs: individual detections



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rpTDEs: individual detections

IN PROGRESS

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Conclusions

- fTDEs very unlikely sources for LISA, but promising for DO
- rpTDE background can be a problem for detectors more sensitive at lower frequency
- rpTDEs could be individually detected? LISA? DO?

QUESTIONS?

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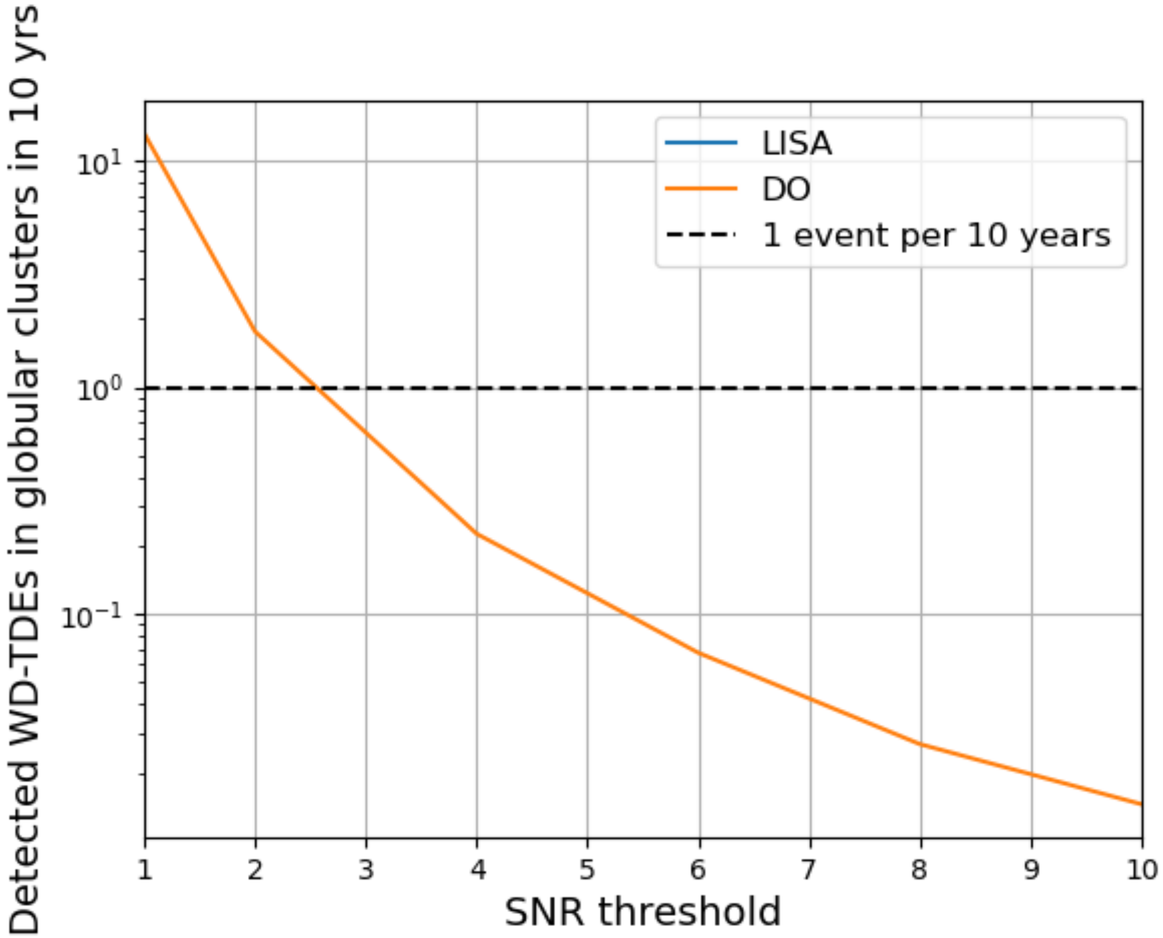
fTDEs: white dwarfs (II)

$$\frac{d^3\dot{N}_{\rm det}^{\rm fTDEs}}{dz dM_\bullet dR_{\rm p}} \approx \frac{d\Gamma(M_{\rm h})}{dR_{\rm p}} \times N_{\rm gc}(M_\bullet) \times \Phi(M_\bullet, z) \times \frac{4\pi\chi^2(z)}{H(z)} \times \Theta(z, M_\bullet, M_*, R_{\rm p})$$



$$N_{\rm gc} \approx \left(\frac{M_\bullet}{4\times 10^5 {\rm M}_\odot}\right)$$

(Burkert & Tremaine10, Harris & Harris 11)

$$M_* = 0.5{\rm M}_\odot, M_{\rm h} = 10^3{\rm M}_\odot,$$
$$10^6{\rm M}_\odot \leq M_\bullet \leq 10^8{\rm M}_\odot$$

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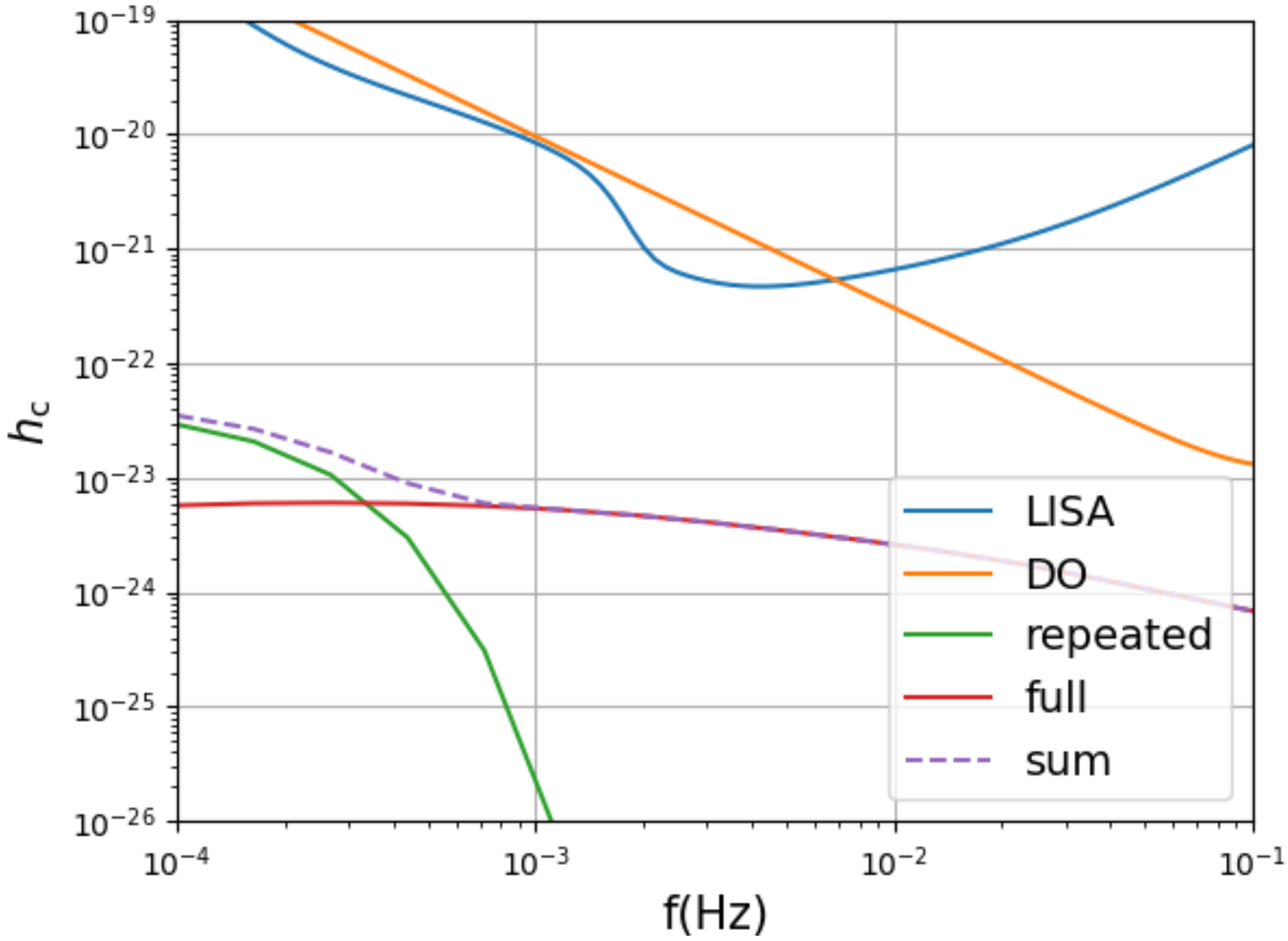
Repeated TDEs + full TDEs



Repeated TDEs

Empty loss cone

Individual detections

$$P < \Delta t_{\rm obs}$$

$$\boxed{\Delta t_{\rm obs} = \tilde{n}\, P + p}$$

$\tilde{n}$: maximum number of subsequent passages